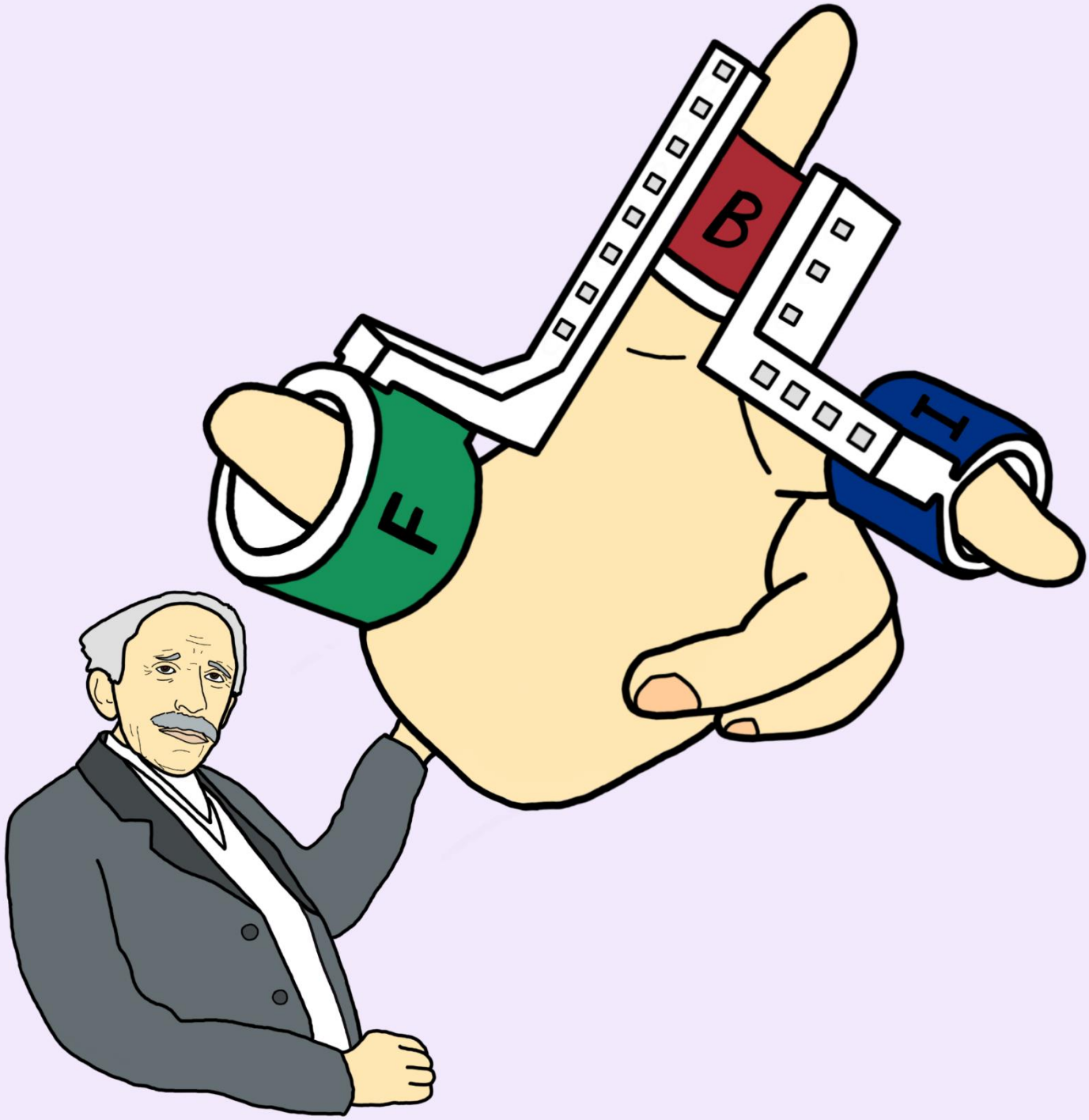
Fleming's Finger Gloves

手指「套」著弗林明



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The University of Hong Kong
香 港 大 學 教 育 學 院

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Teachers' Manual
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1. Introduction

The two 3D-printed teaching models help students visualise Fleming's left-hand rule and the interaction between two parallel straight current-carrying wires.

2. Objectives

Students are expected to

- state the physical quantities represented by the three fingers and their orientations in Fleming's left-hand rule
- apply Fleming's left-hand rule to identify the direction of the magnetic force acting on a straight current-carrying wire in a magnetic field
- recognise the tangential direction of the magnetic field patterns associated with a straight current-carrying wire
- determine the directions of magnetic forces acting on the two parallel straight current-carrying wires

3. Materials

Gadget	Item	Quantity
Finger Gloves (Fig 1)	Finger rings (labelled by F, B, and I, respectively)	3
	L-shape connector (Longer)	1
	L-shape connector (Shorter)	1
B-Pad (Fig 2)	Straw (the same colour as B-field)	1
	Straw (another colour)	1
	B-field arrows	8
	Current arrows	4
	Poster (with circular B-field pattern)	1
	Blu-tack	adequate

Fig.1 Required materials for Finger Gloves

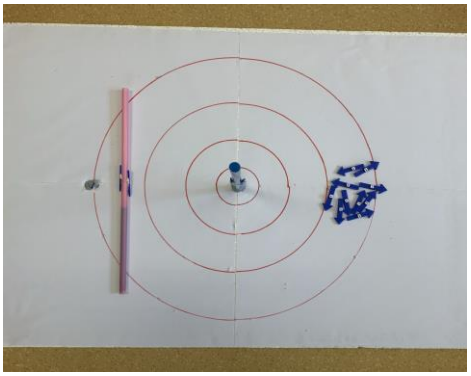


Fig. 2 Required materials of B-Pad

4. Demonstration of the Models

i) 3D printing for the teaching models

1. Download the [fingergloves].stl and [B-Pad].stl file.
2. Import the .stl file to the 3D printer for printing.
3. Select the parameters of 3D printing based on the printer availability.
4. Print all the materials.

(The quality of the 3D printing models depends on the 3D printer's quality and settings)

ii) Assembling of Finger Gloves:

The Finger Gloves (Fig 3) adopt the Lego design; the finger rings can be attached to the L-shaped connectors by inserting their tabs into the holes.

1. Paint the "F", "B", and "I" finger rings with different colours (suggestion: "green" for force, "red" for magnetic field and "blue" for current)
2. Connect the "F" and "B" finger rings with the L-shaped connector (Longer)
3. Connect the "B" and "I" finger rings with the L-shaped connector (Shorter)

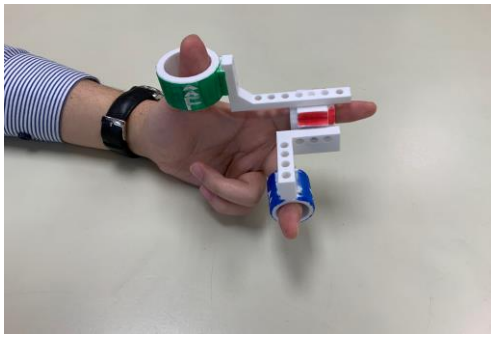


Fig. 3 The assembled Finger Gloves

iii) Suggested demonstration of using B-Pad:

1. Hold the straw (the same colour as B-field) vertically with blu-tack at the centre of the circular B-field shown on the poster.
2. Stick the current arrows on the straws to indicate the direction of the current.
3. Place the B-field arrows on the poster to indicate the tangential direction of the B-field (collaborative work is suggested in this part).
4. Hold another straw vertically within the B-field and put the Finger Gloves over it.
5. Adjust the orientation of the Finger Gloves and determine the direction of magnetic force (Fig. 4).

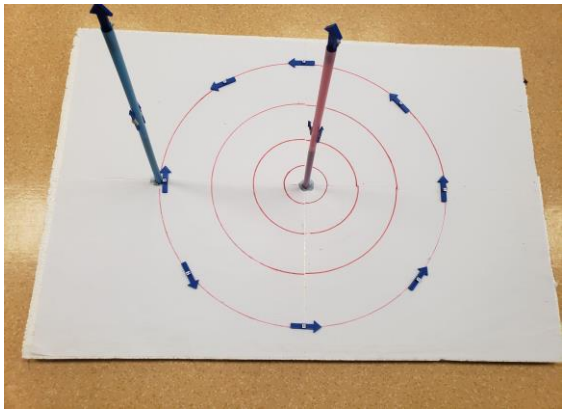


Fig. 4 The assembled B-Pad

5. Suggested Lesson Plan

<table>
<tr><td colspan="2">Key questions of the lesson:
How to apply Fleming's left-hand rule to identify the directions of the magnetic forces acting on the two parallel straight current-carrying wires</td></tr>
<tr><td>Subject
Physics</td><td rowspan="4">Learning Objectives:

Knowledge (Cognitive)
K1. State the physics quantities represented by the three fingers and their orientations in Fleming's left-hand rule
K2. Apply Fleming’s left-hand rule to identify the direction of the magnetic force acting on a straight current-carrying wire in a magnetic field
K3. Recognise the tangential direction of the magnetic field patterns associated with a straight current-carrying wire
K4. Determine the directions of magnetic forces between two parallel straight current-carrying wires</td></tr>
<tr><td>Form
Secondary 5</td></tr>
<tr><td>Topic
Fleming’s left-hand rule</td></tr>
<tr><td>Characteristics of students
1. Weak in spatial cognition</td></tr>
</table>

<table>
<tr><td colspan="5">Topic taught the last lesson:
● Right-hand grip rule</td></tr>
<tr><td colspan="5">Students’ relevant prior knowledge:
● The magnetic field pattern of a straight current-carrying wire</td></tr>
<tr><td colspan="5">Development</td></tr>
<tr><td>Time</td><td>Teacher Activities</td><td>Students Activities</td><td>Remarks</td><td>Objective</td></tr>
<tr><td>5</td><td>Explain Fleming’s left-hand rule.
Invite Ss to put on Finger Gloves.
Guiding Questions:
a. Can you put it on your left hand/right hand?
b. How can we determine the direction of the magnetic force?</td><td>Put finger gloves on both hands.</td><td>Two* Finger Gloves</td><td>K1</td></tr>
</table>

5	Provide a warm-up question (current wire in B-field) and ask the students to solve it with the help of Finger Gloves. *Guiding Questions:* *a. What is the direction of current/ B-field/ and magnetic force?* *b. If the B-field/current is removed, will there be magnetic force?*	Determine the direction of magnetic force in the warm-up question with Finger Gloves.		K1, K2
20	Introduce two parallel straight current-carrying wires (with fixed current directions) • Revisit the right-hand grip rule. • Invite 8 students to stick the B-field arrows on the poster to represent the tangential directions of the magnetic field at different locations. • Use Finger Gloves to determine the direction of magnetic force. *Guiding questions:* *a. Can you describe how the magnetic force is produced?* *b. Which B-field contributes to the magnetic force acting on wire 1?* Reverse the direction of one of the straight current-carrying wires and repeat the activity.	8 students stand around B-Pad and stick the B-field arrows on the poster to indicate the tangential direction of the B-field.	B-Pad, finger gloves	K3, K4
10	Invite students to observe the B-Pad from different angles (i.e. top-view, side-view, and front view) and re-examine the direction of magnetic force. *Guiding questions:* *a. What are the directions of magnetic force from top-view/side-view/front view, respectively?*	Observe the B-Pad from different angles and identify the corresponding directions of magnetic force.		K4

課堂工作紙 學生中文版
弗林明的手指套及 B-Pad

學習目標

- 以弗林明左手定則陳述三根手指所代表的物理量及方向
- 辨別磁場內帶電流長直導線上的磁力方向

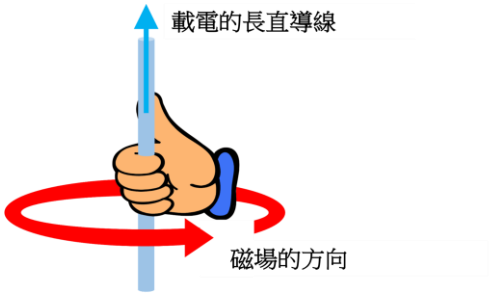
背景

A. 作用在帶電流長直導線上的磁力

當一條帶電流長直導線置於磁場內，並與磁場方向相互垂直，磁力便會作用於長直導線上，且它的方向是同時垂直於磁場方向及電流方向。

B. 帶電流長直導線的右手握拳定則

假設右手握住導線，而拇指指向電流方向，那麼，彎曲的手指就會指向磁場線的方向。透過右手握拳定則，我們就能找出於任何一點的磁力方向。

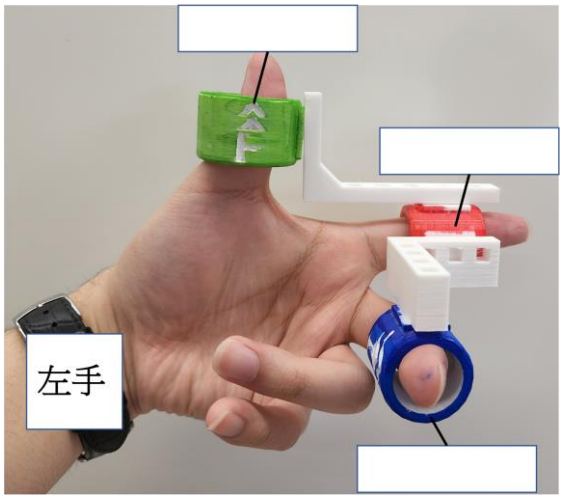


✧ 當另一條帶電的長直導線放置在外磁場內，_____ 就會作用於長直導線上。我們應使用（ 左 / 右 ）手去判斷磁力的方向。

弗林明的手指套: 作用於帶電流導線的磁力

✧ **填空題**

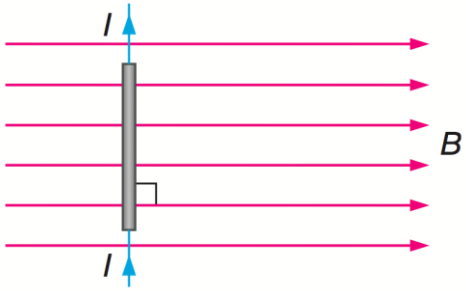
磁力	電流	磁場

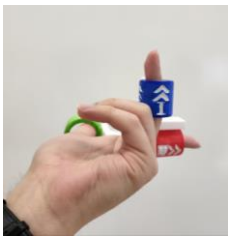
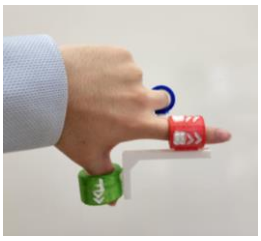
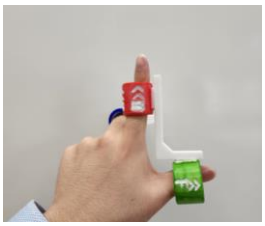


三根手指相互 _____ 。

✧ **例子一**

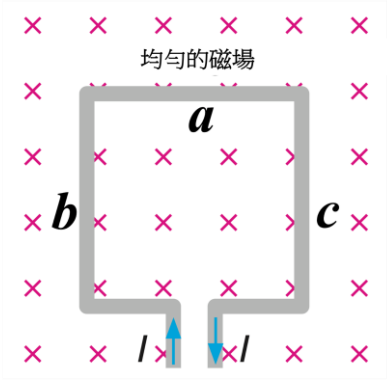
下列哪張圖片正確指出作用於長直導線的磁力方向？

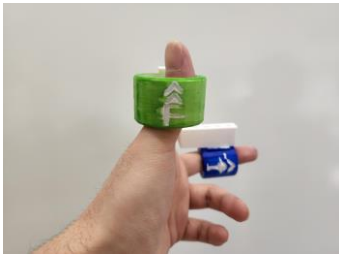
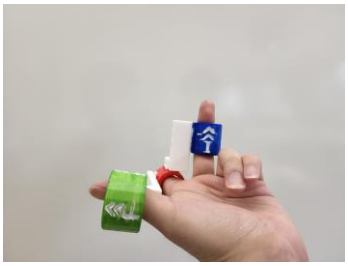


A	B	C
		

✧ **例子二**

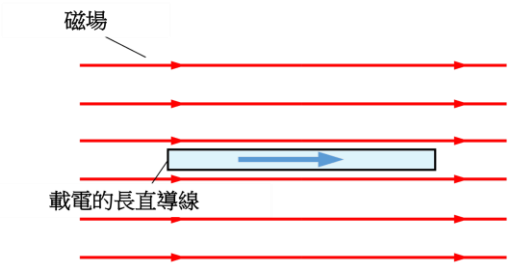
下列三張圖片顯示了作用在線圈上不同部分的磁力方向。試將圖片與相應的部分匹配。



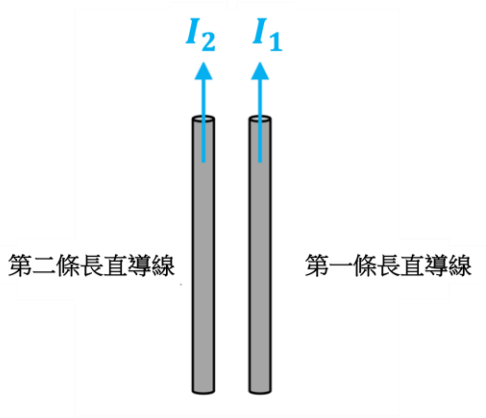
✧ **例子三**

你能以弗林明的手指套找出作用於長直導線的磁力方向嗎？如不能找出，試解釋原因。



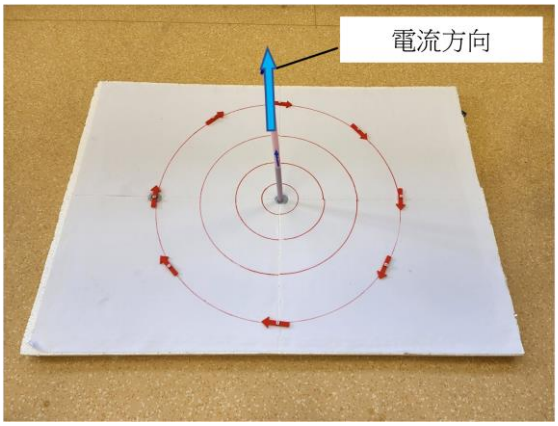
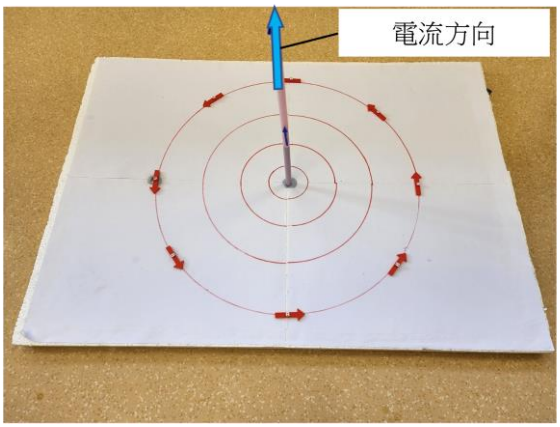
B-Pad: 兩條帶電流長直導線之間的磁力

✧ 例子四

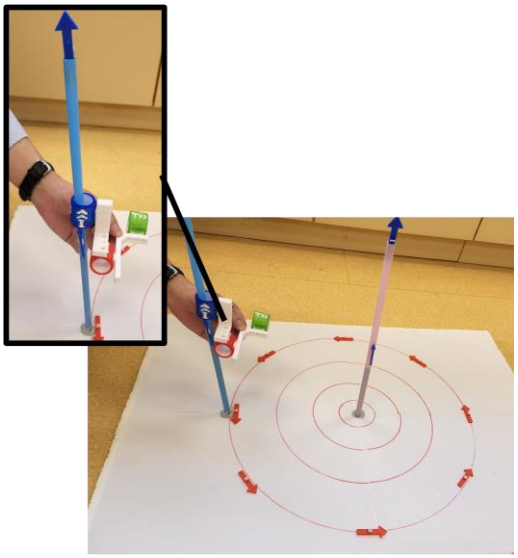
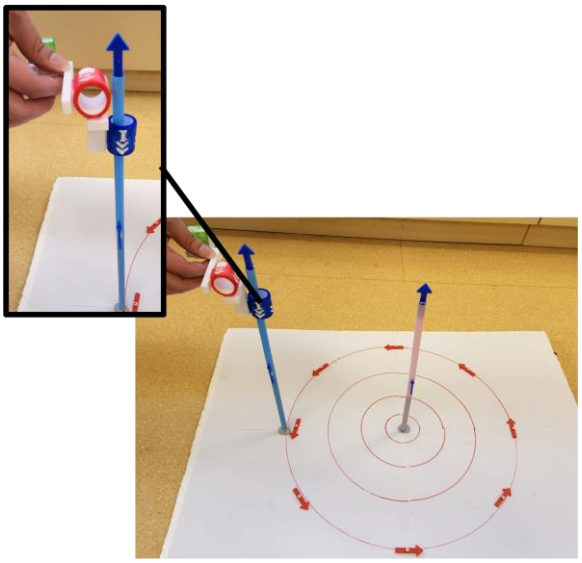


活動中，我們將會透過弗林明的手指套及 B-Pad 探究兩條長直導線之間的磁力。**飲管表示兩條長直導線**，而藍色箭頭則代表其電流的方向。

步驟一: 下列哪張圖片能正確指出長直導線（紅色飲管）產生的磁場方向？

A	B
	

步驟二: 將第二條長直導線（藍色飲管）放置在磁場內，且其電流方向與第一條導線相同。下列哪張圖片正確指出作用於第二條長直導線的磁力方向？

A	B
	

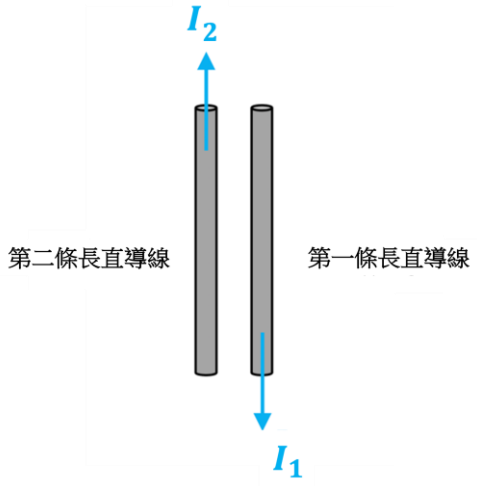
步驟三: 將另一個弗林明的手指套套在第一條長直導線（紅色飲管）上。有磁力作用於該導線嗎？試解釋你的答案。

總結:

兩條**電流方向相同**的長直導線之間存在一對相互（ **吸引 / 排斥** ）的磁力。

✧ **例子五**

重複例子四的步驟，試判斷下圖各長直導線作用於另一條長直導線的磁力方向（相互吸引或相互排斥）。



總結:

兩條**電流方向相反**的長直導線之間存在一對相互（ **吸引 / 排斥** ）的磁力。

Student Handout English Version
Finger Gloves and B-Pad

Objectives

- State the physics quantity represented by the three fingers and their orientations in Fleming's left-hand rule
- Identify the direction of the magnetic force acting on a straight current-carrying wire in a magnetic field

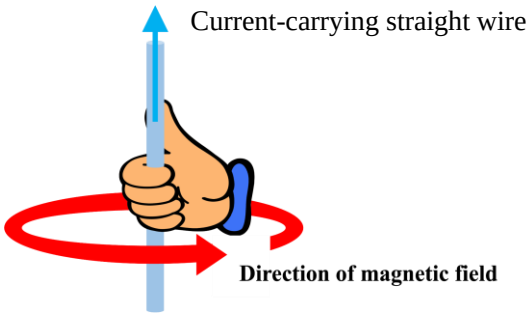
Background

A. Magnetic force on a current-carrying conductor

When a current-carrying straight wire is placed at a right angle to a uniform magnetic field, the wire experiences a magnetic force perpendicular to the field lines and the current.

B. Right-hand grip rule for a current-carrying straight wire

If the right-hand grips the wire with the thumb pointing to the current direction, then the other fingers will curl to the B-field direction. Using the right-hand grip rule, we can determine the direction of the magnetic field at any given point.

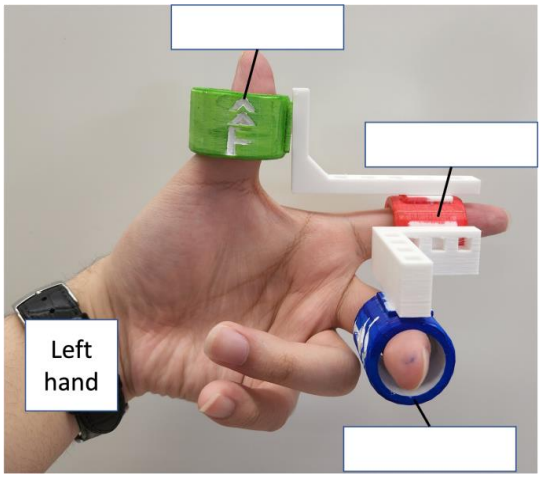


✧ When a current-carrying wire is placed within an external magnetic field, a _____ force will act on the wire. We should use our (left / right) hand to determine the direction of the magnetic force.

Finger Gloves: Magnetic force on a current-carrying conductor

✧ Fill in the blanks.

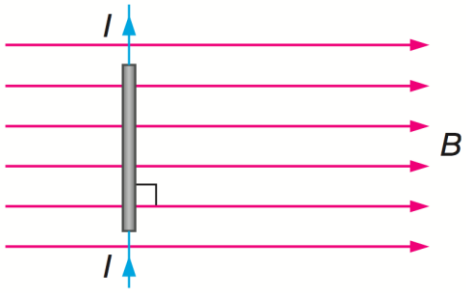
magnetic force	current	magnetic field

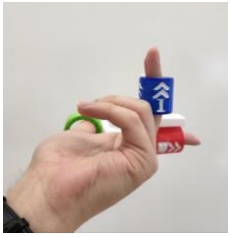


The three fingers are _____ to each other.

✧ **Example 1**

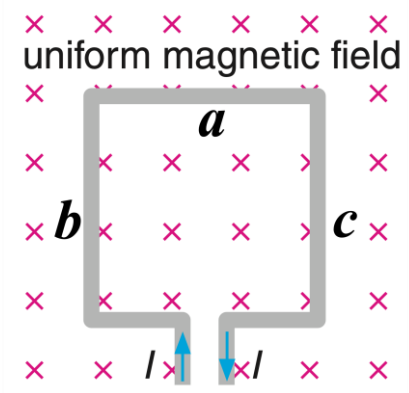
Which of the following images correctly indicates the magnetic force acting on the straight wire?

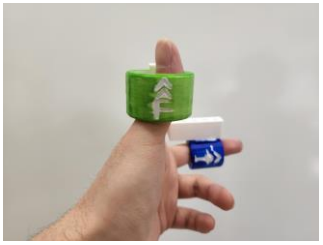
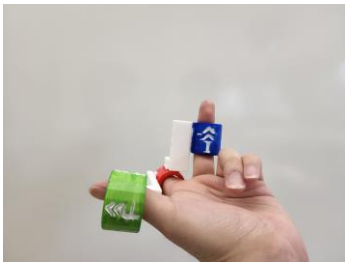


A	B	C
		

✧ **Example 2**

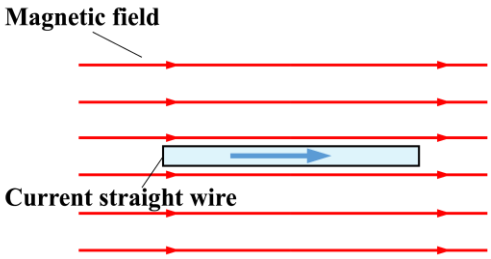
The three images below show the application of Fleming's left-hand rule on different coil segments below. Match the images with the corresponding segments.



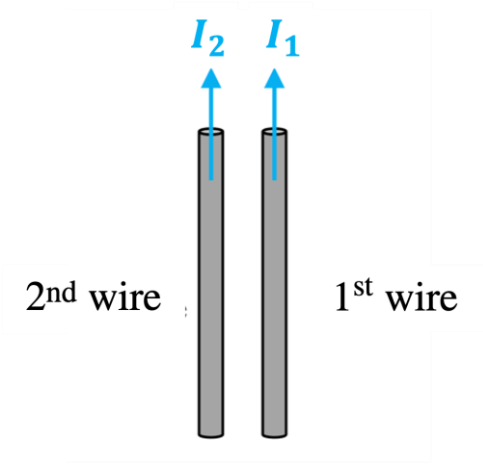
✧ **Example 3**

Can you state the direction of the magnetic force acting on the current straight wire by using Fleming's Finger Gloves? If not, explain the reason.



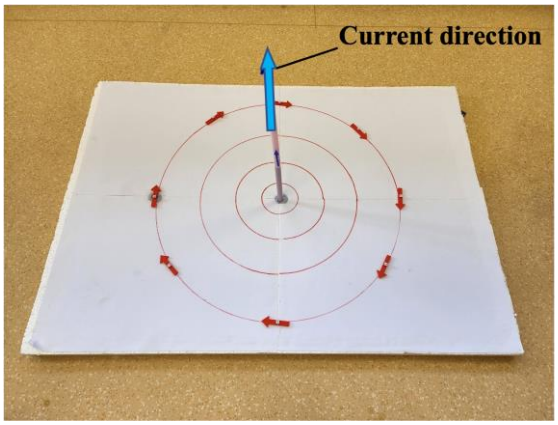
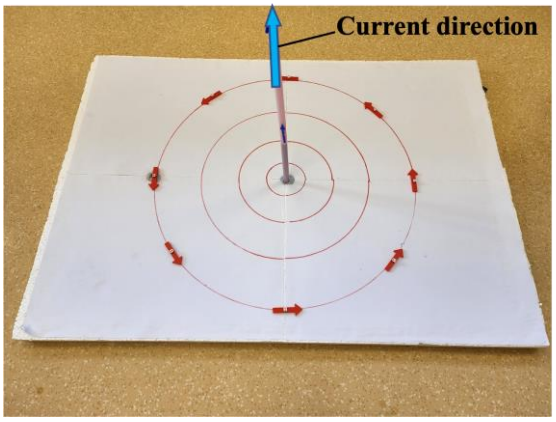
B-Pad: Magnetic forces between two current-carrying straight wires

✧ **Example 4**

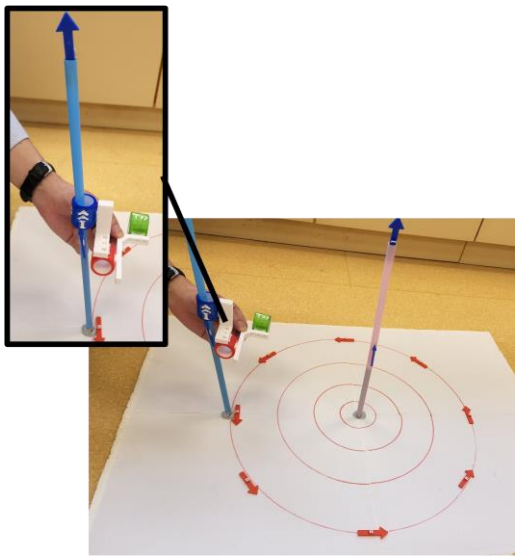
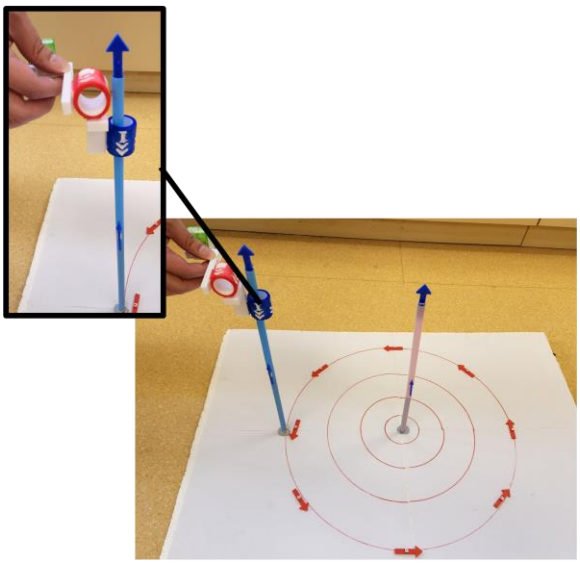


In this activity, we will use the B-Pad to investigate the magnetic forces between two current-carrying straight wires. **Straws are used to represent the current-carrying wires**, and the blue arrows indicate the current directions.

Step 1: Which image correctly shows the magnetic field direction produced by the current-carrying wire (the red straw)?

A	**B**
	

Step 2: A second wire (the blue straw) is then put inside the magnetic field. The current direction is the same as the first wire. Which of the following image correctly indicates the magnetic force acting on the second wire?

A	B
	

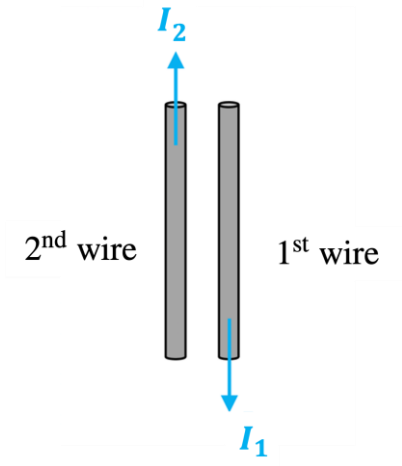
Step 3: Put another Fleming's Finger Gloves on the first wire (the red straw). Does the first wire also experience a magnetic force? Explain your answer.

Conclusion:

A pair of (**attractive / repulsive)** magnetic forces exist between two straight wires carrying **current flowing in the same direction**.

✧ **Example 5**

By repeating the steps in Example 4, determine the directions of magnetic forces acting on the two wires (attractive or repulsive).



Conclusion:

A pair of (**attractive / repulsive**) magnetic forces exist between two straight wires carrying **current flowing in the opposite direction**.

課堂工作紙 學生中文版（參考答案）
弗林明的手指套及 B-Pad

學習目標

- 以弗林明左手定則陳述三根手指所代表的物理量及方向
- 辨別磁場內帶電流長直導線上的磁力方向

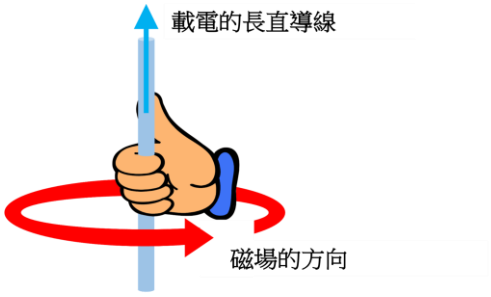
背景

A. 作用在帶電流長直導線上的磁力

當一條帶電流的長直導線置於磁場內，並與磁場方向相互垂直，磁力便會作用於長直導線上，且它的方向是同時垂直於磁場方向及電流方向。

B. 帶電流長直導線的右手握拳定則

假設右手握住導線，而拇指指向電流方向， 那麼，彎曲的手指就會指向磁場線的方向。透過右手握拳定則，我們就能找出於任何一點的磁力方向。

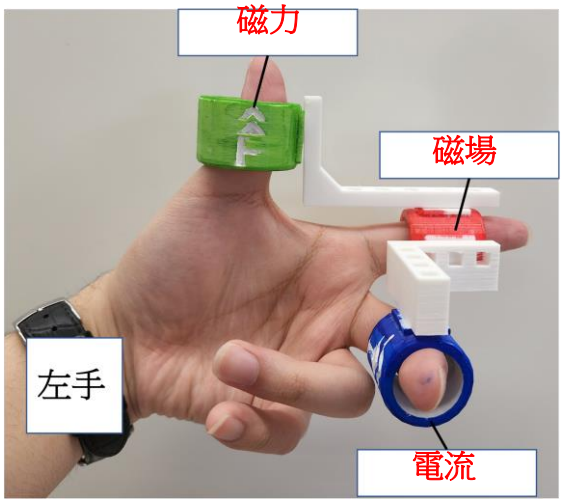


✧ 當另一條帶電的長直導線放置在外磁場內， ___磁力___ 就會作用於長直導線上。我們應使用（左 / 右）手去判斷磁力的方向。

弗林明的手指套: 作用在長直導線的磁力

✧ **填空題**

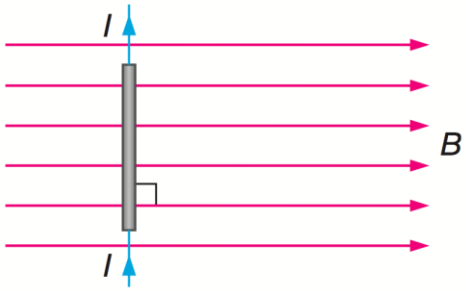
磁力	電流	磁場

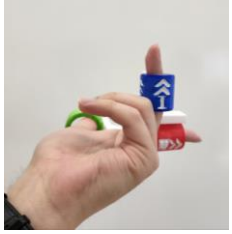
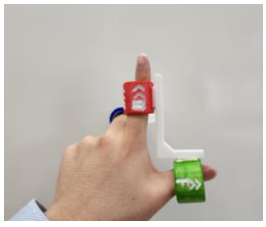


三根手指相互 垂直 。

✧ **例子一**

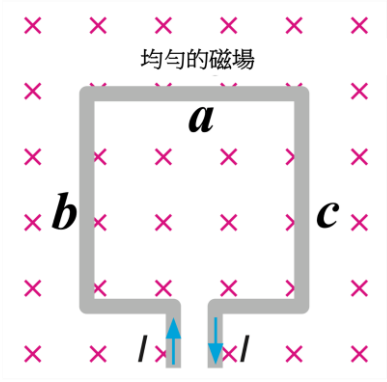
下列哪張圖片正確指出作用於長直導線的磁力方向？

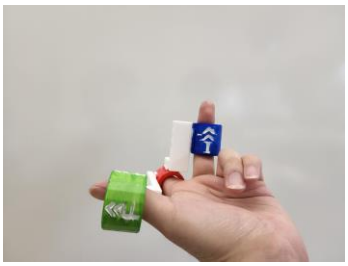


A	B	C
		

✧ 例子二

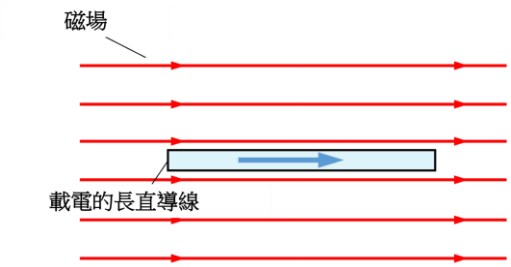
下列三張圖片顯示了作用在線圈上不同部分的磁力方向。試將圖片與相應的部分匹配。



a	*c*	*b*
		

✧ 例子三

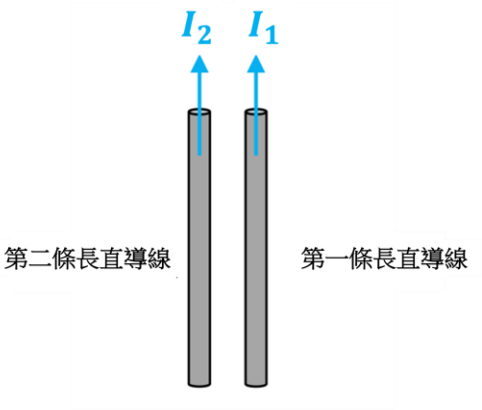
你能以弗林明的手指套找出作用於長直導線的磁力方向嗎？如不能找出，試解釋原因。



因為電流方向平行於磁場方向，所以沒有磁力作用於導線。

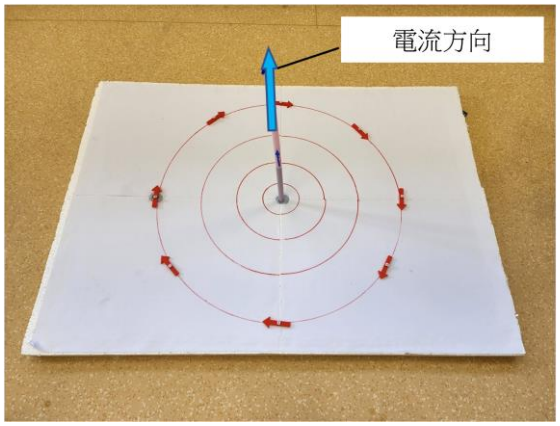
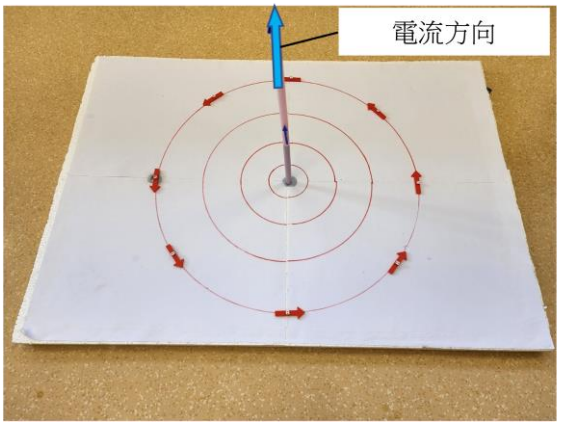
B-Pad: 兩條帶電流長直導線之間的磁力

✧ 例子四

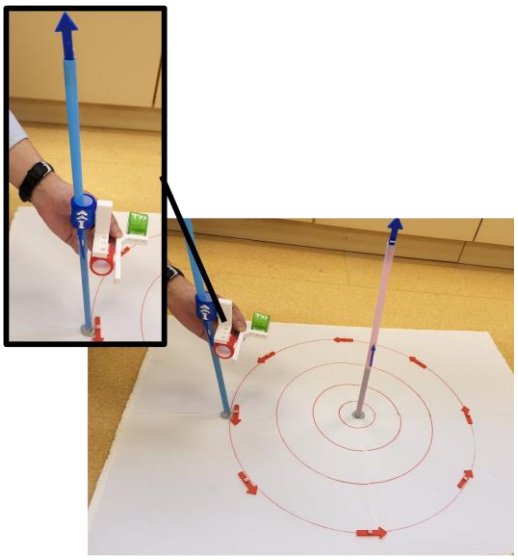
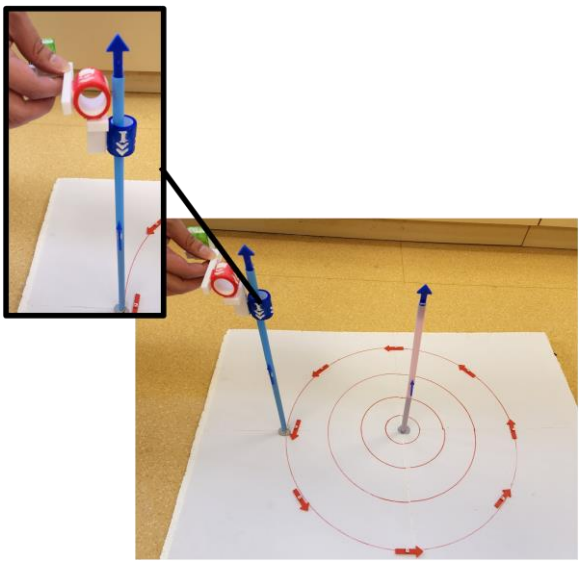


活動中，我們將會透過弗林明的手指套及 B-Pad 探究兩條長直導線之間的磁力。**飲管表示兩條長直導線**，而藍色箭頭則代表其電流的方向。

步驟一: 下列哪張圖片能正確指出長直導線（紅色飲管）產生的磁場方向？

A	**B**
	

步驟二: 將第二條長直導線（藍色飲管）放置在磁場內，且其電流方向與第一條導線相同。下列哪張圖片正確指出作用於第二條長直導線的磁力方向？

A	B
	

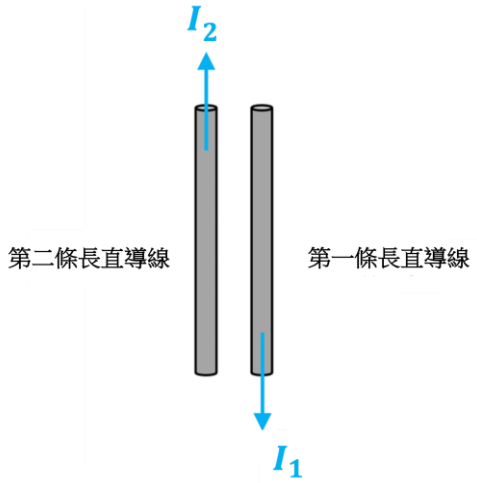
步驟三: 將另一個弗林明的手指套套在第一條長直導線（紅色飲管）上。有磁力作用於該導線嗎？試解釋你的答案。

有，磁力的方向指向左。
因為第一條長直導線上的電流和第二條長直導線產生的磁場互相垂直。

總結:
兩條**電流方向相同**的長直導線之間存在一對相互（ 吸引 / **排斥** ）的磁力。

✧ **例子五**

重複例子四的步驟，試判斷下圖各長直導線作用於另一長直導線的磁力方向（相互吸引或相互排斥）。



作用於第一條長直導線的磁力向右，而作用於第二條長直導線的磁力向左。
故此，兩條長直導線之間有相互排斥的磁力。

總結:

兩條**電流方向相反**的長直導線之間存在一對相互（ **吸引** / 排斥 ）的磁力。

Student Handout English Version (with answers)
Finger Gloves and B-Pad

Objectives

- State the physics quantity represented by the three fingers and their orientations in Fleming's left-hand rule
- Identify the direction of the magnetic force acting on a straight current-carrying wire in a magnetic field

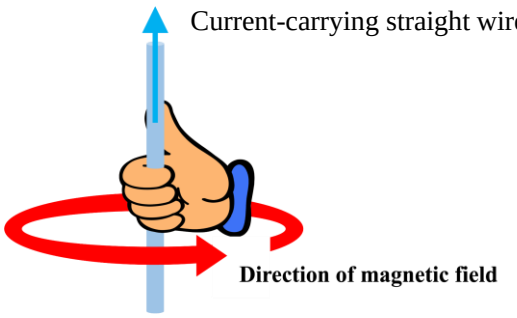
Background

A. Magnetic force on a current-carrying conductor

When a current-carrying straight wire is placed at a right angle to a uniform magnetic field, the wire experiences a magnetic force perpendicular to the field lines and the current.

B. Right-hand grip rule for a current-carrying straight wire

If the right-hand grips the wire with the thumb pointing to the current direction, then the other fingers will curl to the B-field direction. Using the right-hand grip rule, we can determine the direction of the magnetic field at any given point.

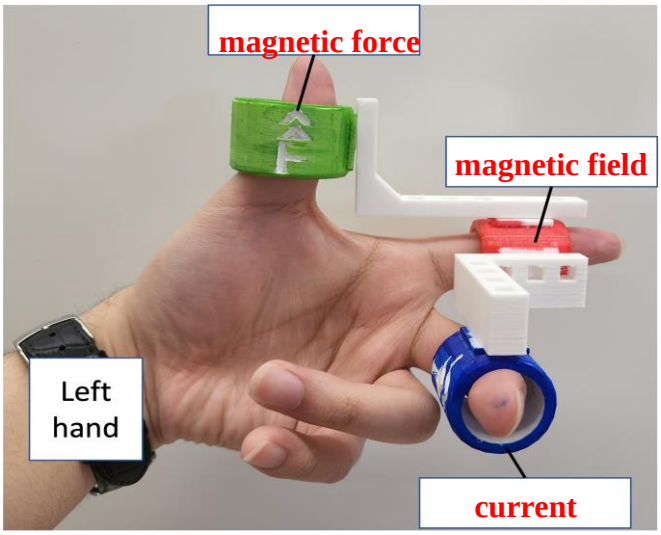


✧ When a current-carrying wire is placed within an external magnetic field, a **magnetic force** force will act on the wire. We should use our (**left**/right) hand to determine the direction of the magnetic force.

Finger Gloves: Magnetic force on a current-carrying conductor

✧ Fill in the blanks.

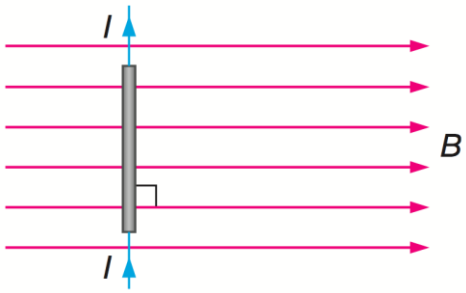
Magnetic force	current	magnetic field

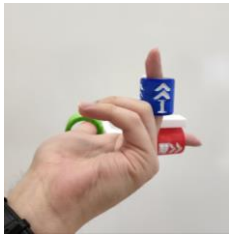
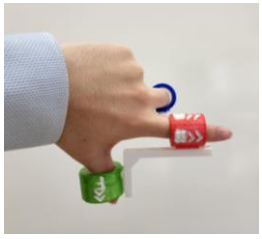


The three fingers are **perpendicular** to each other.

✧ **Example 1**

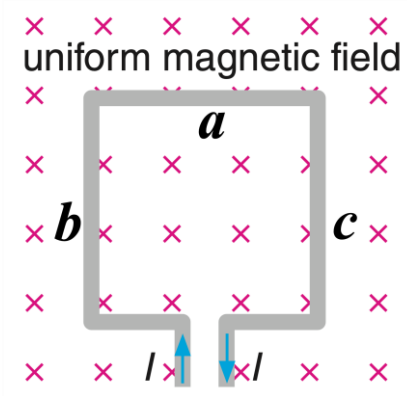
Which of the following images correctly indicates the magnetic force acting on the straight wire?

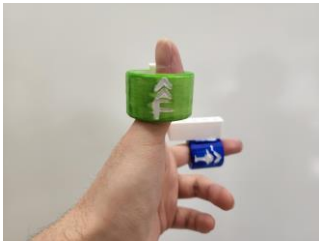
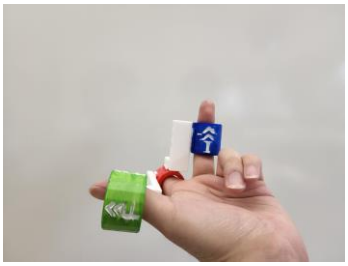


A	B	C
		

✧ **Example 2**

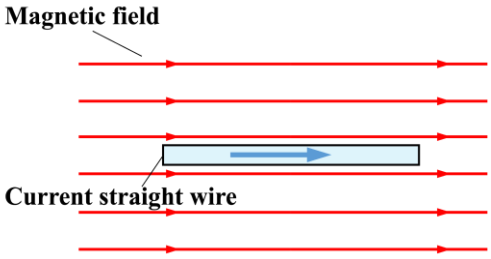
✧ The three images below show the application of Fleming's left-hand rule on different coil segments below. Match the images with the corresponding segments.



a	*c*	*b*
		

✧ **Example 3**

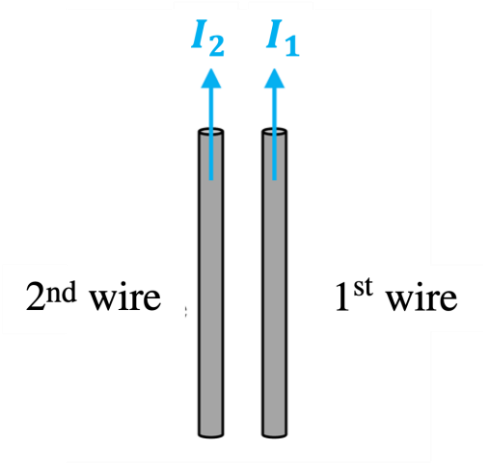
Can you state the direction of the magnetic force acting on the current straight wire by using Fleming's Finger Gloves? If not, explain the reason.



No. the direction of current is parallel to that of the magnetic field.

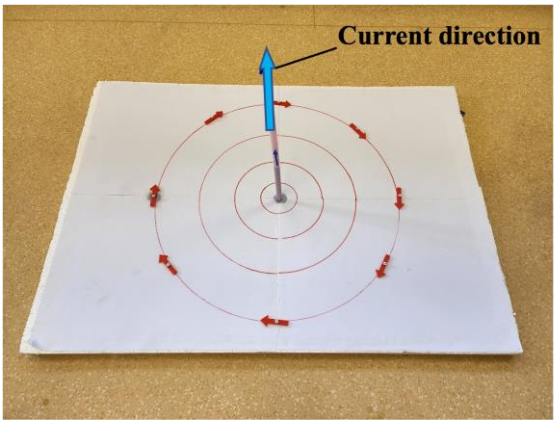
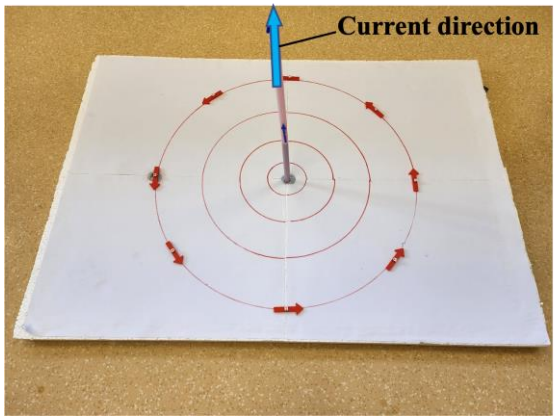
B-Pad: Magnetic forces between two current-carrying straight wires

✧ **Example 4**

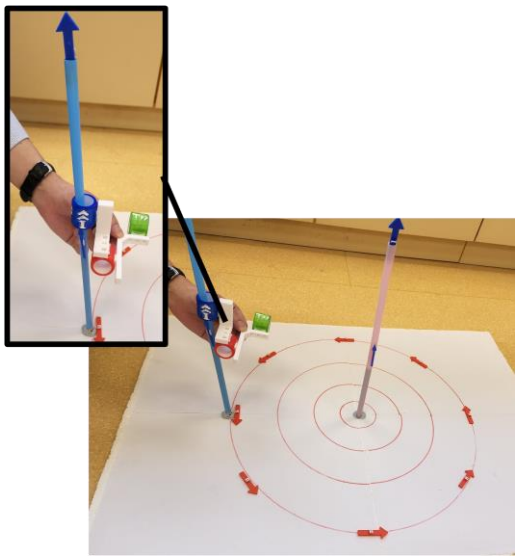
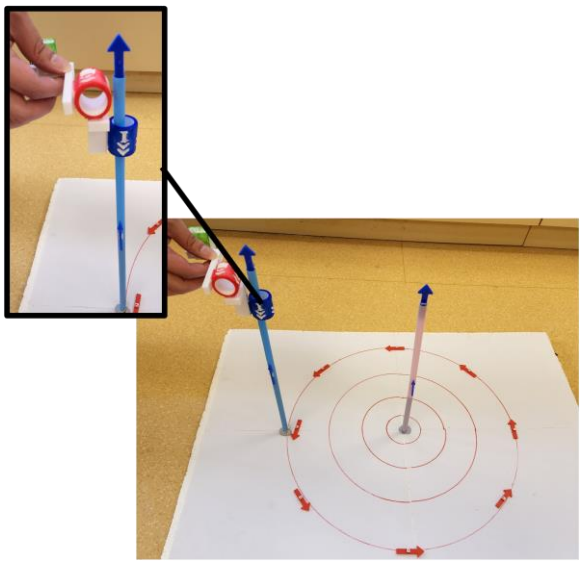


In this activity, we will use the B-Pad to investigate the magnetic forces between two current-carrying straight wires. **Straws are used to represent the current-carrying wires**, and the blue arrows indicate the current directions.

Step 1: Which image correctly shows the magnetic field direction produced by the first current-carrying wire (the red straw)?

A	**B**
	

Step 2: The second wire (the blue straw) is then put inside the magnetic field. The current direction is the same as the first wire. Which of the following image correctly indicates the magnetic force acting on the second wire?

A	B
	

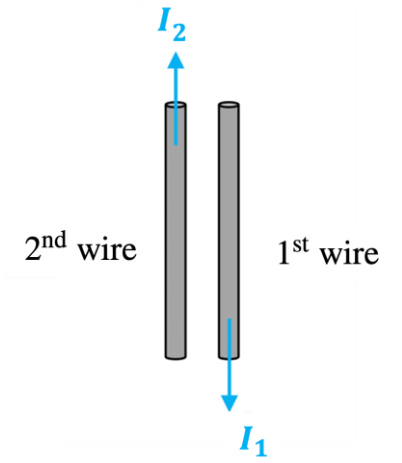
Step 3: Put another Fleming's Finger Gloves on the first wire (red straw). Does the first wire also experience a magnetic force? Explain your answer.

Yes, the magnetic force points to the left.
This is because the current on the first wire is perpendicular to the B-field produced by the second wire.

Conclusion:
A pair of (**attractive** / **repulsive**) magnetic forces exist between two straight wires carrying **current flowing in the same direction**.

✧ **Example 5**

By repeating the steps in Example 4, determine the directions of magnetic forces acting on the two wires (attractive or repulsive).



The direction of magnetic force acting on the first wire points to the right and the direction of magnetic force acting on the second wire poits to the left.

Therefore, there is a pair of repulsive magnetic forces between them.

Conclusion:

A pair of (**attractive / repulsive)** magnetic forces exist between two straight wires carrying **current flowing in the opposite direction**.

Fleming's Finger Gloves

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