

Welcome Back to
Physics 1308

Magnetic Fields

Sir Joseph John Thomson
18 December 1856 – 30 August 1940



Announcements

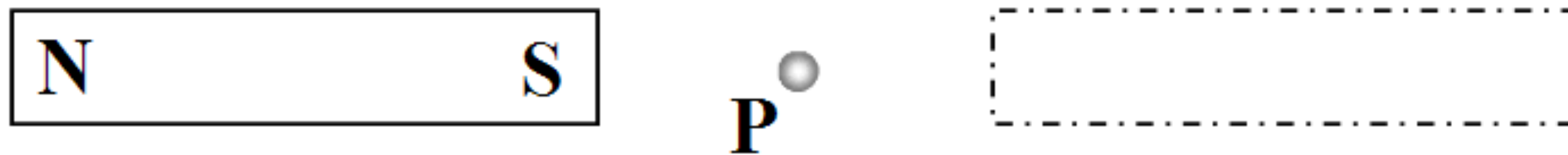
- **Assignments for Thursday, October 25th:**
 - Reading: Chapter 28.7 - 28. 8
 - Watch Video: https://youtu.be/ikYu3K3_104 — Lecture 16 - Magnetic Fields and Current Loops
- **Homework 9 Assigned - due before class on Tuesday, October 30th.**
- **Midterm Exam 2 will be handed back in class on Thursday.**



**KEEP
CALM
AND
ITS
QUIZ TIME**

Review Question 1

Consider the two rectangular areas shown with a point P located at the midpoint between the two areas. The rectangular area on the left contains a bar magnet with the south pole near point P. The rectangle on the right is initially empty. How will the magnetic field at P change, if at all, when a second bar magnet is placed on the right rectangle with its south pole near point P?



- A) The direction of the magnetic field will not change, but its magnitude will decrease.
- B) The direction of the magnetic field will not change, but its magnitude will increase.
- C) The magnetic field at P will be zero tesla.
- D) The direction of the magnetic field will change and its magnitude will increase.
- E) The direction of the magnetic field will change and its magnitude will decrease.

Review Question 2

A negatively-charged particle travels parallel to magnetic field lines within a region of space. Which one of the following statements concerning the force exerted on the particle is true?

- (a) The force is directed perpendicular to the magnetic field.
- (b) The force is perpendicular to the direction in which the particle is moving.
- (c) The force slows the particle.
- (d) The force accelerates the particle.
- (e) The force has a magnitude of zero newtons.

Key Concept Review

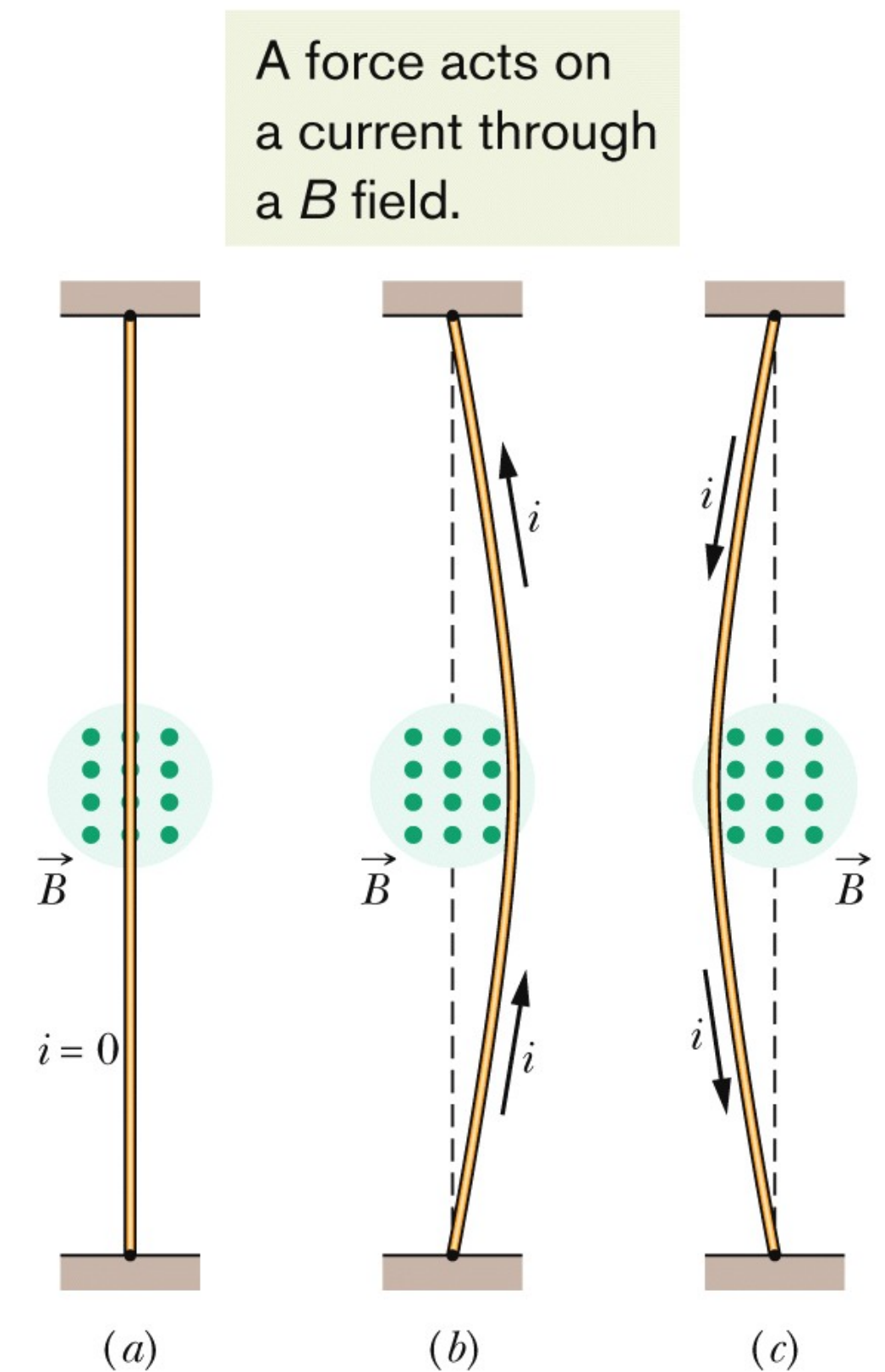
A straight wire carrying a current i in a uniform magnetic field experiences a sideways force

$$\vec{F}_B = i\vec{L} \times \vec{B} \quad (\text{force on a current})$$

Here L is a length vector that has magnitude L and is directed along the wire segment in the direction of the (conventional) current

The magnitude of the force is given by

$$F_B = iLB \sin \phi$$



Question 1

Three long, straight, identical wires are inserted one at a time into a magnetic field directed due east. Wire A carries a current of 2 A in the direction of 45° south of east. Wire B carries a current of 8 A, due north. Wire C carries a current of 10 A, due west. Rank the wires in terms of the magnitude of the magnetic force on each wire, with the largest force listed first and the smallest force listed last.

Answer: $B > A > C$

recall: $F_B = iLB\sin\phi$

Instructor Problem

A horizontal power line carries a current of 5.00×10^3 A from south to north. Earth's magnetic field ($60.0 \mu\text{T}$) is directed toward the north and inclined downward at 70.0° to the horizontal. Find the magnitude and direction of the magnetic force on 100.0 m of the line due to Earth's field.

Given:

$$i = 5000 \text{ A}$$

$$|\vec{B}| = 60 \mu\text{T}$$

$$\phi = 70.0^\circ$$

$$L = 100 \text{ m}$$

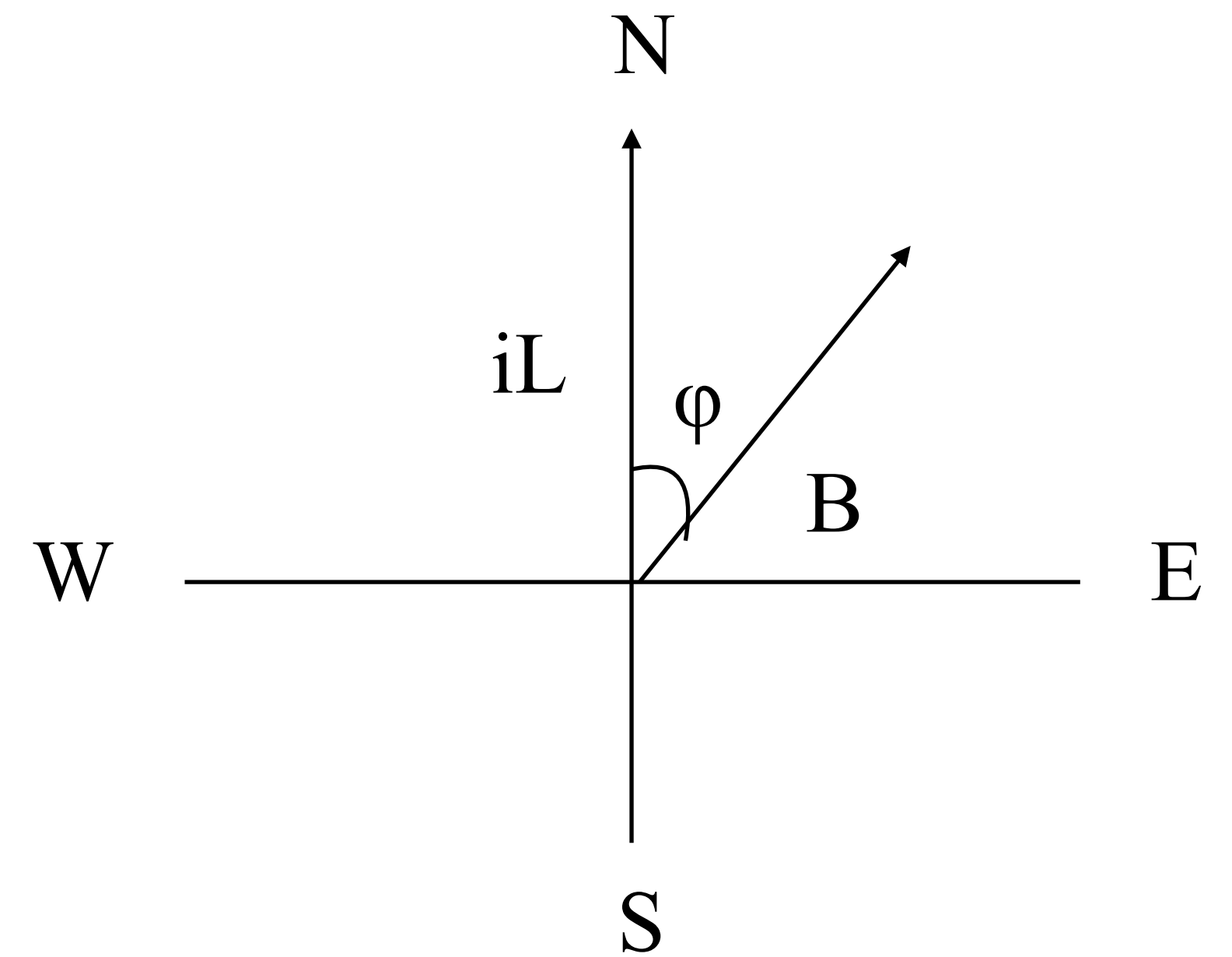
Part A:

The magnitude of the force is given by the formula

$$F = iLB \sin \phi$$

$$= (5000 \text{ A})(100 \text{ m})(60 \times 10^{-6} \text{ T})(\sin 70)$$

$$F = 28.1 \text{ N}$$



Part B:

From equation (1) we can see that we need to apply the right hand rule to determine the direction.

$$\vec{F} = i\vec{L} \times \vec{B} \quad \dots(1)$$

Right-Hand Rule:

1. Make a set of coordinate axes using the index finger, middle finger, and thumb on our right hand, as indicated below.

2. The basic equation governing magnetic force on a line of charge is

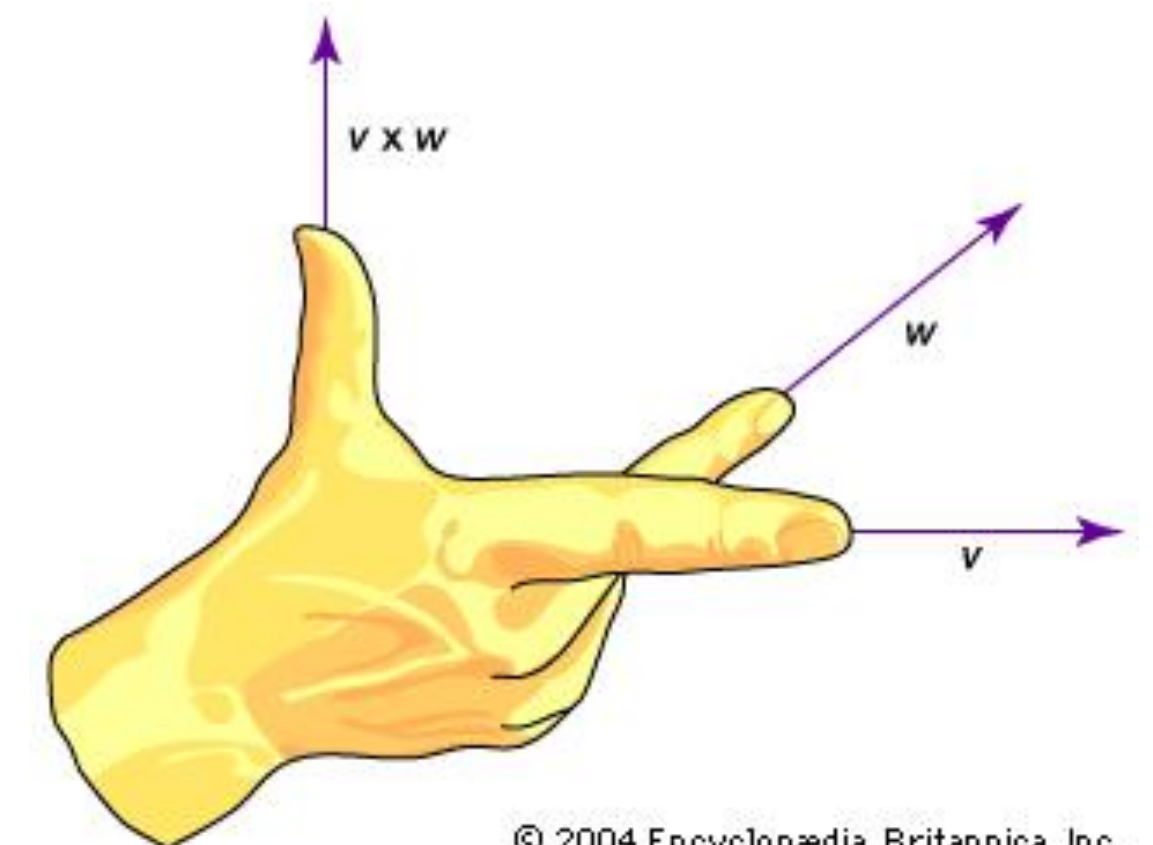
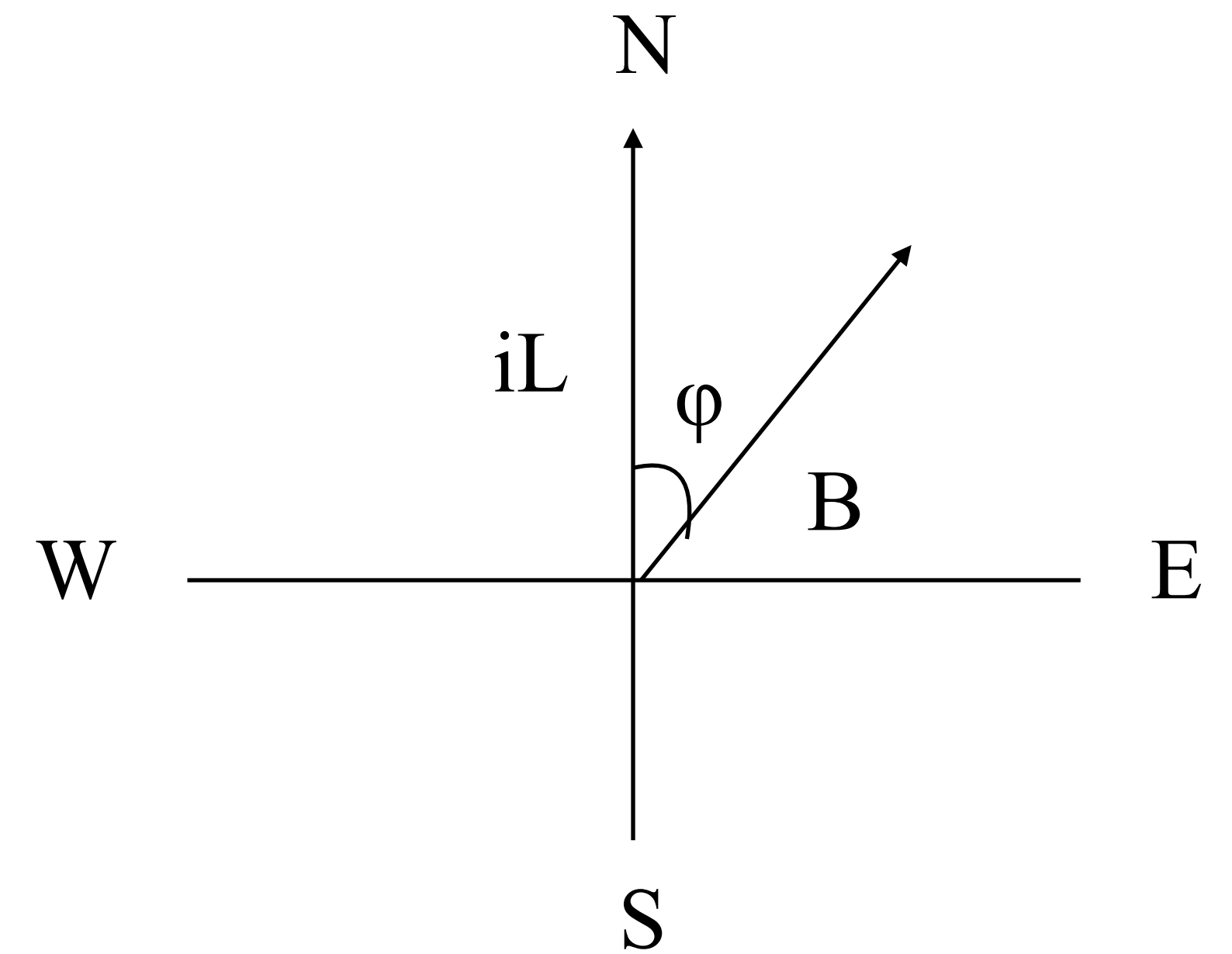
$$\vec{F} = i\vec{L} \times \vec{B}$$

3. Point the index finger in the direction of the length vector.

4. Point your middle finger in the direction of the magnetic field vector.

5. Your thumb now indicates the direction of the force.

Answer: West



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Student Problem

A single-turn current loop, carrying a current of 4.00 A, is in the shape of a right triangle with sides 50.0, 120. and 130. cm. The loop is in a uniform magnetic field of magnitude 75.0 mT whose direction is parallel to the current in the 130. cm side of the loop.

- A) What is the magnitude of the magnetic force on the 130. cm side?
- B) What is the magnitude of the magnetic force on the 50.0 cm side?
- C) What is the magnitude of the magnetic force on the 120. cm side?
- D) What is the magnitude of the net force on the loop?

Given: $i = 4.00 \text{ A}$
 $B = 75.0 \text{ mT}$ (parallel to 130 cm side)

First pick a coordinate system.

Next, establish the angles of the triangle.

$$\tan \theta = \frac{\textit{opposite}}{\textit{adjacent}} \longrightarrow \theta = \tan^{-1} \left(\frac{50.0 \text{ cm}}{120 \text{ cm}} \right) \longrightarrow \theta = 22.6^\circ$$

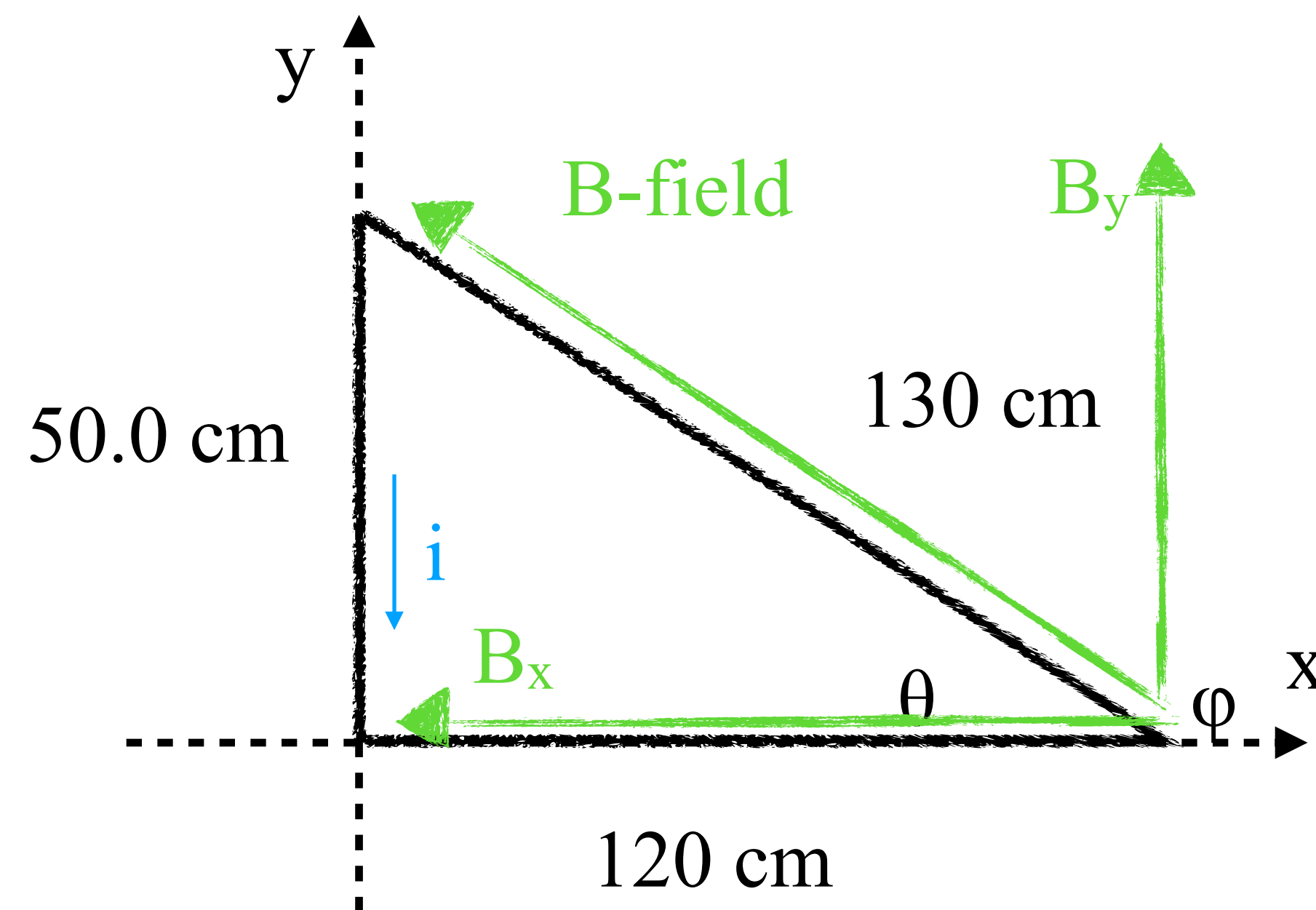
$$\phi = 180^\circ - 22.6^\circ = 157.4^\circ$$

Assume current goes counterclockwise around the triangle.

The x- and y- components of the magnetic field are then found using trigonometry.

$$\cos \theta = \frac{\textit{adjacent}}{\textit{hypotenuse}} \longrightarrow B_x = -B \cos \theta = -(75 \times 10^{-3} \text{ T}) \cos(22.6^\circ) = -0.0692 \text{ T}$$

$$\sin \theta = \frac{\textit{opposite}}{\textit{hypotenuse}} \longrightarrow B_y = B \sin \theta = (75 \times 10^{-3} \text{ T}) \sin(22.6^\circ) = 0.0288 \text{ T}$$



Part A:

To find the magnitude of the force of the magnetic field we employ the equation

$$\vec{F} = i\vec{L} \times \vec{B}$$

This equation tells us that there is only a force when the current is perpendicular to the magnetic field. The B-field and 130 cm segment are parallel. Thus, the force is zero.

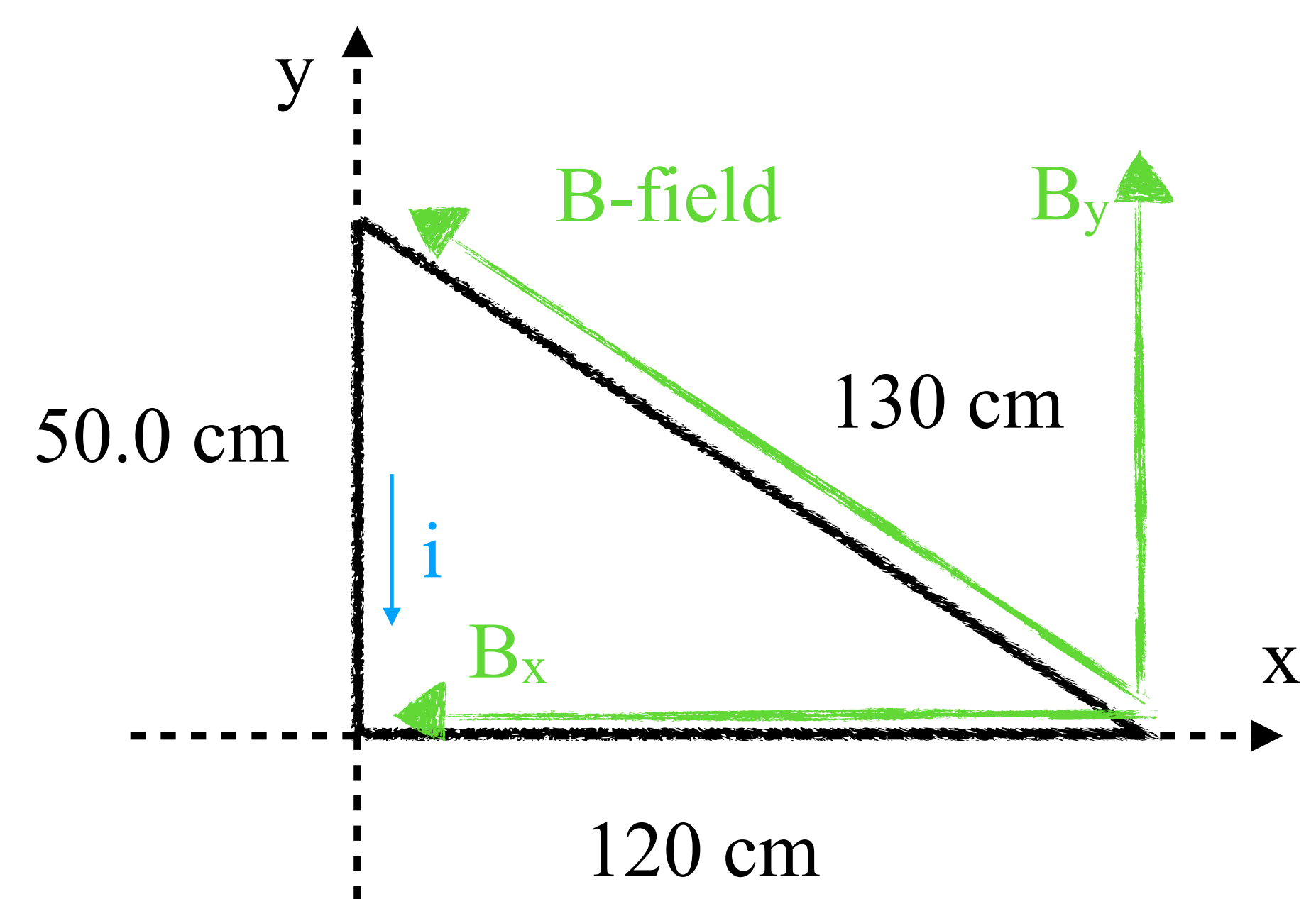
$$\vec{F} = 0 \text{ N}$$

Part B:

Again we will employ the magnetic force equation — this time on the 50.0 cm side.

$$\vec{F} = i\vec{L} \times \vec{B}$$

In this calculation we are crossing the unit vectors \hat{j} and \hat{i} . We need to recall our cross product rules.



1. Any “cyclic permutation” of the symbols yields a positive cross-product.

$$\hat{i} \times \hat{j} = \hat{k}$$

$$\hat{k} \times \hat{i} = \hat{j}$$

$$\hat{j} \times \hat{k} = \hat{i}$$

2. If we swap an pair of unit vectors on the LHS of the above equation, the RHS changes sign.

$$\hat{j} \times \hat{i} = -\hat{k}$$

$$\hat{i} \times \hat{k} = -\hat{j}$$

$$\hat{k} \times \hat{j} = -\hat{i}$$

3. The cross-product of any unit vector with itself is zero.

$$\hat{i} \times \hat{i} = \hat{j} \times \hat{j} = \hat{k} \times \hat{k} = 0$$

Part A:

To find the magnitude of the force of the magnetic field we employ the equation

$$\vec{F} = i\vec{L} \times \vec{B}$$

This equation tells us that there is only a force when the current is perpendicular to the magnetic field. The B-field and 130 cm segment are parallel. Thus, the force is zero.

$$\vec{F} = 0 \text{ N}$$

Part B:

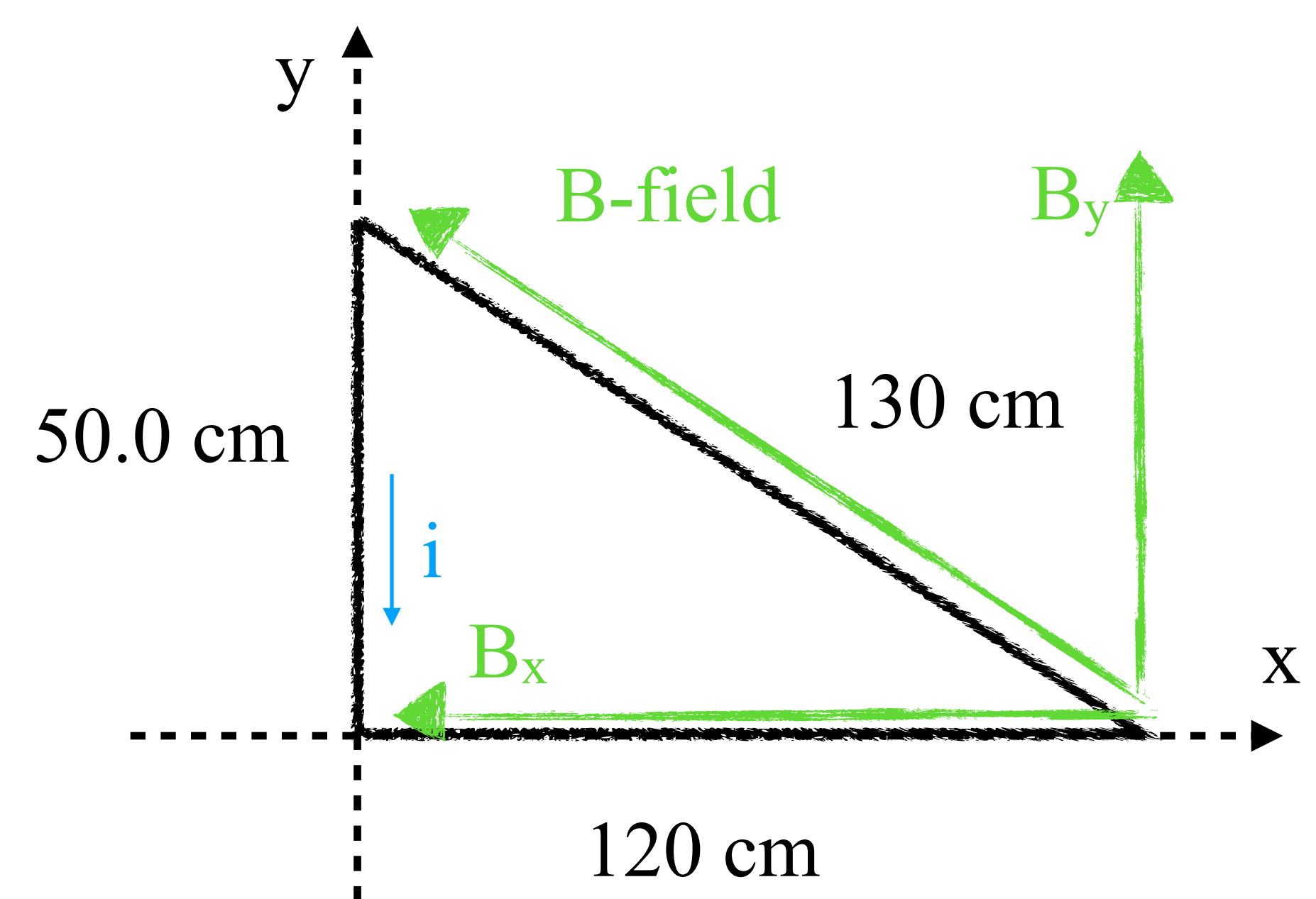
Again we will employ the magnetic force equation — this time on the 50.0 cm side.

$$\vec{F} = i\vec{L} \times \vec{B}$$

In this calculation we are crossing the unit vectors \hat{j} and \hat{i} , so the resultant unit vector is $-\hat{k}$.

$$\vec{F} = iL_y B_x (-\hat{k}) = (4.00 \text{ A})(-0.500 \text{ m})(-0.0692 \text{ T})(-\hat{k})$$

$$\vec{F} = 0.138 \text{ N}(-\hat{k}) \rightarrow |\vec{F}| = 0.138 \text{ N}$$



Part C:

Again we will employ the magnetic force equation — this time on the 120 cm side.

$$\vec{F} = i\vec{L} \times \vec{B}$$

In this calculation we are crossing the unit vectors \hat{i} and \hat{j} , so the resultant unit vector is \hat{k} .

$$\vec{F} = iL_x B_y (\hat{k}) = (4.00 \text{ A})(1.20 \text{ m})(0.0288 \text{ T})(\hat{k})$$

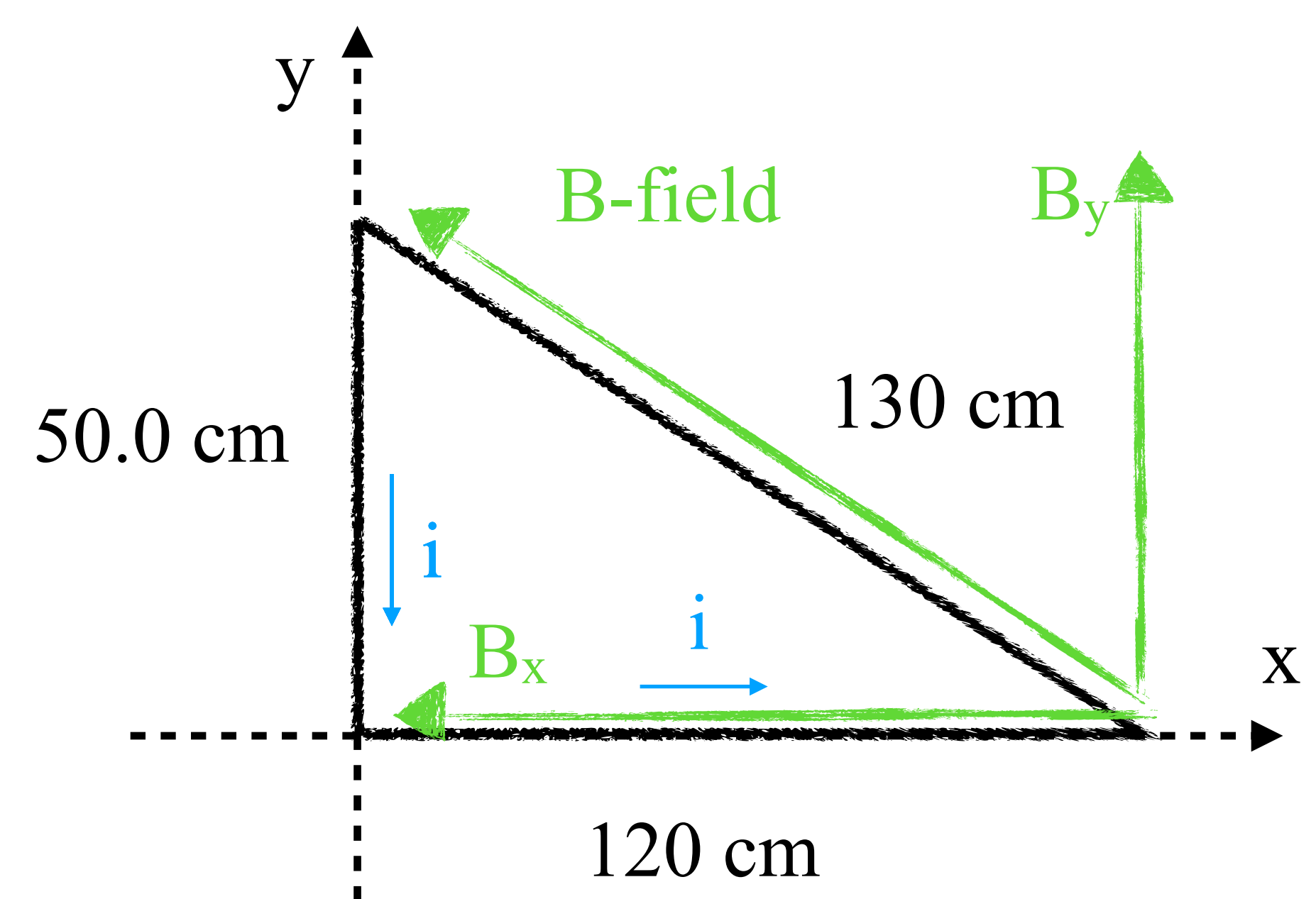
$$\vec{F} = 0.138 \text{ N}(\hat{k}) \rightarrow |\vec{F}| = 0.138 \text{ N}$$

Part D:

The resultant force is just the sum of the forces around the loop.

$$\sum \vec{F} = F_{130} + F_{50} + F_{120} = 0 \text{ N} - 0.138 \text{ N} + 0.138 \text{ N}$$

$$\sum \vec{F} = 0 \text{ N}$$



The End for Today!



FoxTrot