Magnetism pre-class assignment

Due: 11:59pm on Thursday, July 28, 2022

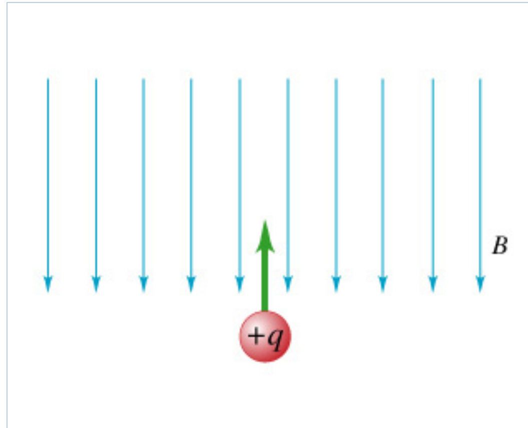
You will receive no credit for items you complete after the assignment is due. Grading Policy

Magnetic Force on Charged Particles Conceptual Question

For each of the situations below, a charged particle enters a region of uniform magnetic field. Determine the direction of the force on each charge due to the magnetic field.

Part A

Determine the direction of the force on the charge due to the magnetic field.



Hint 1. Determining the direction of a magnetic force

A charged particle moving through a region of magnetic field experiences a magnetic force, unless the velocity and magnetic field are parallel. If the velocity is parallel to the magnetic field, then the force is zero. Otherwise, the direction of the force can be found by using the right-hand rule.
To employ the right hand rule:

1. Open your hand so that it is completely flat, and point the fingers of your right hand in the direction of the velocity vector.
2. Rotate your wrist until you can bend your fingers to point in the direction of the magnetic field.
3. The direction of your outstretched thumb is the direction of the magnetic force on a positive charge.

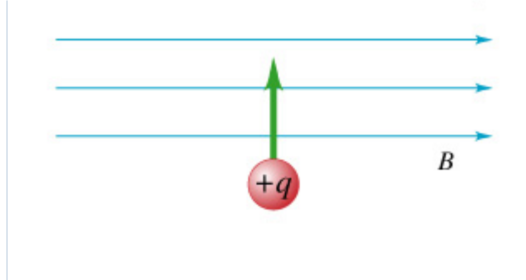
ANSWER:

- ○ $\vec{F}$ points into the page.
- ○ $\vec{F}$ points out of the page.
- ○ $\vec{F}$ points neither into nor out of the page and $\vec{F} \neq 0$.
- ◉ $\vec{F} = 0$.

Correct

Part B

Determine the direction of the force on the charge due to the magnetic field.



Hint 1. Determining the direction of a magnetic force

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To employ the right hand rule:

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2. Rotate your wrist until you can bend your fingers to point in the direction of the magnetic field.
3. The direction of your outstretched thumb is the direction of the magnetic force on a positive charge.

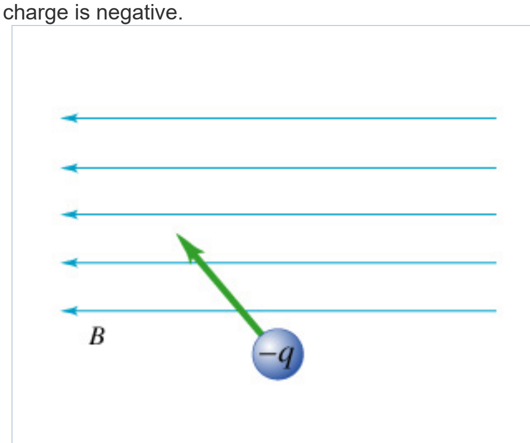
ANSWER:

- ○ $\vec{F}$ points out of the page.
- ◉ $\vec{F}$ points into the page.
- ○ $\vec{F}$points neither into nor out of the page and $\vec{F} \neq 0$.
- ○ $\vec{F} = 0$.

Correct

Part C

Determine the direction of the force on the charge due to the magnetic field. Note that the charge is negative.



Hint 1. Effect of a magnetic field on a negative charge

You can use the right-hand rule to determine the direction of the force exerted on a positive charge. Once you find the direction of the force that would be exerted on a positive charge, the force on a negative charge will point in the opposite direction.

ANSWER:

- ○ $\vec{F}$ points out of the page.
- ◉ $\vec{F}$ points into the page.
- ○ $\vec{F}$ points neither into nor out of the page and $\vec{F} \neq 0$.
- ○ $\vec{F} = 0$.

Correct

Magnetic Force Vector Drawing

For each of the situations below, a charged particle enters a region of uniform magnetic field. Draw a vector to represent the direction of the magnetic force on the particle.

Part A

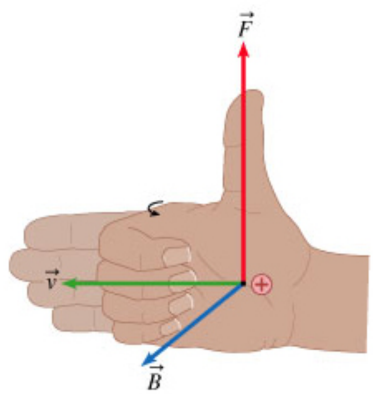
Draw the vector starting at the location of the charge. The location and orientation of the vector will be graded. The length of the vector will not be graded.

Hint 1. The right-hand rule for magnetic force

A charged particle moving through a region of magnetic field experiences a magnetic force. This force is directed perpendicular to both the velocity vector and the magnetic field vector at the point of interaction. The requirement that the force be perpendicular to both of the other vectors specifies the direction of the force to within an algebraic sign. This algebraic sign is determined by the *right-hand rule*. To employ the right-hand rule:

1. Spread your right thumb and index finger apart by 90 degrees.
2. Orient your hand so that your index finger points in the direction of the velocity.
3. Curl your fingers toward the direction of the magnetic field.

If the charge is positive, your thumb is now pointing in the direction of the force as shown.

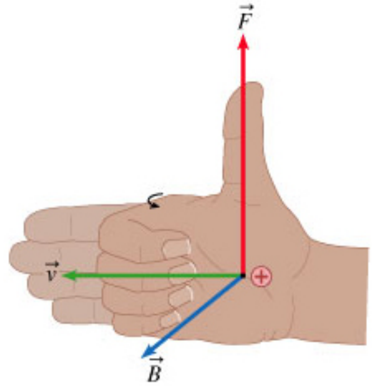


If the charge is negative, the force is in the direction opposite your thumb.

Hint 2. Apply the right-hand rule

1. Spread your right thumb and index finger apart by 90 degrees.
2. Orient your hand so that your index finger points in the direction of the velocity.
3. Curl your fingers toward the direction of the magnetic field.

Your hand should be shaped as seen in the figure.



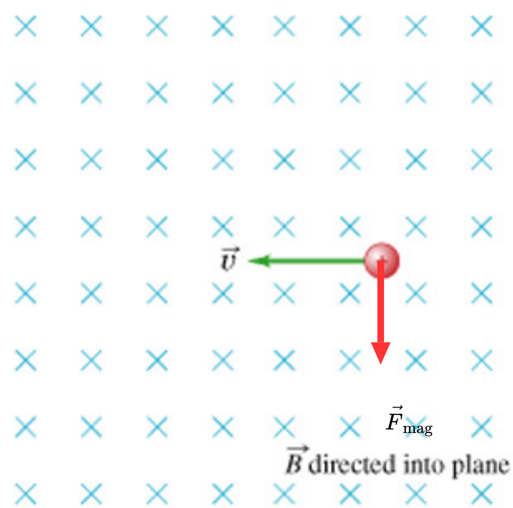
At this point, is your thumb pointing up or down?

ANSWER:

- up
- down

ANSWER:

No elements selected



Correct

Part B

Draw the vector starting at the location of the charge. The location and orientation of the vector will be graded. The length of the vector will not be graded.

Hint 1. Apply the right-hand rule

1. Spread your right thumb and index finger apart by 90 degrees.
2. Orient your hand so that your index finger points in the direction of the velocity.
3. Curl your fingers toward the direction of the magnetic field.

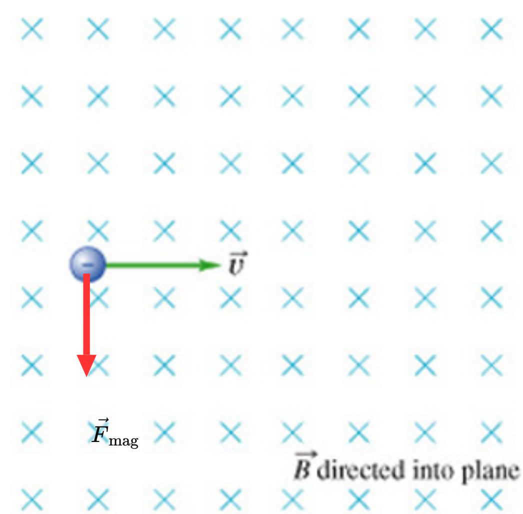
At this point, is your thumb pointing up or down?

ANSWER:

- (selected) up
- down

ANSWER:

No elements selected



Correct

Part C

Draw the vector starting at the location of the charge. The location and orientation of the vector will be graded. The length of the vector will not be graded.

Hint 1. Apply the right-hand rule

1. Spread your right thumb and index finger apart by 90 degrees.
2. Orient your hand so that your index finger points in the direction of the velocity.
3. Curl your fingers toward the direction of the magnetic field.

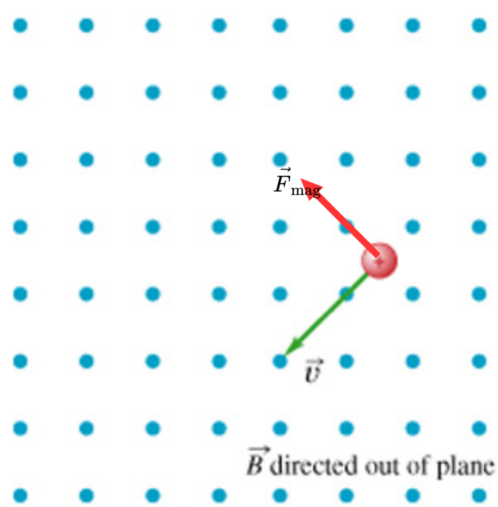
At this point, what direction is your thumb pointing?

ANSWER:

- ○ up and to the right
- ◉ up and to the left
- ○ down and to the right
- ○ down and to the left

ANSWER:

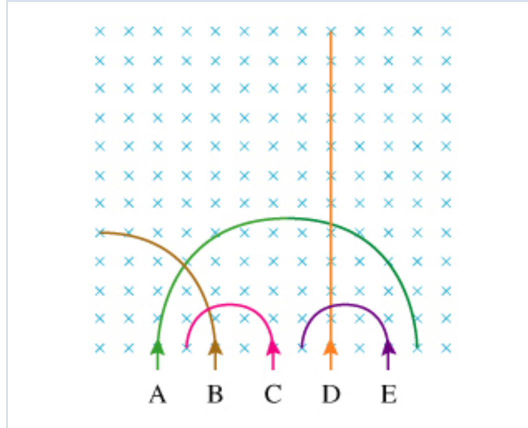
No elements selected



Correct

Charged Particles Moving in a Magnetic Field Ranking Task

Five equal-mass particles (A–E) enter a region of uniform magnetic field directed into the page. They follow the trajectories illustrated in the figure.



Part A

Which particle (if any) is neutral?

Hint 1. Neutral particles

Since the magnitude of the magnetic force acting on a particle is given by

$$F = qvB\sin\theta,$$

a neutral particle (with $q = 0$) will not experience a magnetic force.

ANSWER:

- ○ particle A
- ○ particle B
- ○ particle C
- ◉ particle D
- ○ particle E
- ○ none

Correct

Part B

Which particle (if any) is negatively charged?

Hint 1. Find the direction of the magnetic force

The direction of the magnetic force is determined by the right-hand rule. With the given directions for velocity and magnetic field, what is the direction of the magnetic force on a positively charged particle?

ANSWER:

- left
- right

ANSWER:

- particle A
- particle B
- particle C
- particle D
- particle E
- none

Correct

Part C

Rank the particles on the basis of their speed.

Rank from largest to smallest. To rank items as equivalent, overlap them.

Hint 1. Determining velocity based on particle trajectories

A charged particle moving in a uniform magnetic field follows a circular trajectory. By Newton's second law, the magnetic force acting on the particle must be equal to the product of its mass and acceleration:

$$qvB\sin\theta = ma.$$

In our scenario, the velocity and field vectors are perpendicular, so $\theta = 90 \text{ degrees}$. Also, since the particle moves along a circular path, the acceleration must equal the expression for centripetal acceleration:

$$qvB = m\frac{v^2}{r}.$$

This can be solved for velocity to yield

$$v = \frac{qBr}{m}.$$

Thus, the speed of a particle can be determined by measuring the radius of its circular path in a known magnetic field, assuming that you also know the charge and mass of the particle.

ANSWER:

Reset Help

A B C D E

largest		smallest

☑ The correct ranking cannot be determined.

Correct

Part D

Rank the particles A, B, C, and E on the basis of their speed.

Rank from largest to smallest. To rank items as equivalent, overlap them.

ANSWER:

Reset Help

A B C E

largest		smallest

☑ The correct ranking cannot be determined.

Correct

Part E

Now assume that particles A, B, C, and E all have the same magnitude of electric charge. Rank the particles A, B, C, and E on the basis of their speed.

Rank from largest to smallest. To rank items as equivalent, overlap them.

Hint 1. Charged particle trajectories in magnetic fields

Particles A, B, C, and E are charged. A charged particle moving in a uniform magnetic field follows a circular trajectory. The speed of the particle has two distinct effects on the radius of its circular path. First, the faster the particle moves, the larger the magnetic force acting on it, by

$$F = qvB\sin\theta.$$

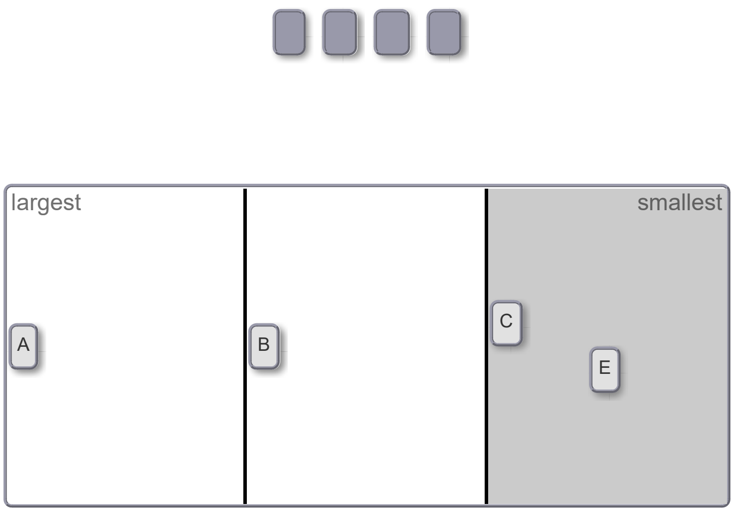
However, the faster it moves, the larger its centripetal acceleration, by

$$a_{\text{centripetal}} = \frac{v^2}{r},$$

and therefore the larger the force needed to keep it in its circular path.

ANSWER:

Reset Help



The correct ranking cannot be determined.

Correct

Exercise 27.2

A particle with a mass of 1.98×10^{-4} kg carries a negative charge of - 3.30×10^{-8} C . The particle is given an initial horizontal velocity that is due north and has a magnitude of 4.30×10^{4} $\mathrm{m/s}$.

Part A

What is the magnitude of the minimum magnetic field that will keep the particle moving in the earth's gravitational field in the same horizontal, northward direction?

ANSWER:

B = 1.37 T

Correct

Part B

What is the direction of the minimum magnetic field?

ANSWER:

- west
- east (selected)
- north
- south

Correct

± Determining the Velocity of a Charged Particle

A particle with a charge of $-$ 5.20 nC is moving in a uniform magnetic field of $\vec{B} = -($ 1.24 T $)\hat{k}$. The magnetic force on the particle is measured to be $\vec{F} = -($ 3.80×10^{-7} N $)\hat{\imath}+($ 7.60×10^{-7} N $)\hat{\jmath}$.

Part A

Are there components of the velocity that cannot be determined by measuring the force?

Hint 1. Magnetic force on a moving charged particle

Recall the following formula:

$$\vec{F} = q\vec{v} \times \vec{B}.$$

If you know $\vec{B}$, does $\vec{v} \times \vec{B}$ uniquely define $\vec{v}$?

ANSWER:

- yes (selected)
- no

Correct

Part B

Calculate the *x* component of the velocity of the particle.

Express your answer in meters per second to three significant figures.

Hint 1. Relation between $\vec{v}$ and $\vec{F}$

Which component of the force depends on the *x* component of the velocity?

ANSWER:

- *x*
- *y* (selected)

ANSWER:

v_x = -118 $\mathrm{m/s}$

Correct

Part C

Calculate the *y* component of the velocity of the particle.

Express your answer in meters per second to three significant figures.

Hint 1. Relation between $\vec{v}$ and $\vec{F}$

Which component of the force depends on the *y* component of the velocity?

ANSWER:

- (●) *x*
- ( ) *y*

ANSWER:

v_y = -58.9 $\mathrm{m/s}$

Correct

Part D

Calculate the scalar product $\vec{v} \cdot \vec{F}$. Work the problem out symbolically first, then plug in numbers after you've simplified the symbolic expression.

Express your answer in watts to three significant figures.

Hint 1. Formula for dot product

The dot product of two vectors $\vec{A}$ and $\vec{B}$ is given by

$$\vec{A} \cdot \vec{B} = A_x B_x + A_y B_y + A_z B_z.$$

ANSWER:

0 W

Correct

Part E

What is the angle between $\vec{v}$ and $\vec{F}$?

Express your answer in degrees to three significant figures.

Hint 1. Another dot product formula

Recall that

$$\vec{A} \cdot \vec{B} = \left|\vec{A}\right| \left|\vec{B}\right| \cos\theta,$$

where θ is the angle between $\vec{A}$ and $\vec{B}$.

ANSWER:

90 °

Correct

Notice that the dot product of the velocity and the force is zero. This will always be the case. Since $\vec{F} = q\vec{v} \times \vec{B}$, $\vec{F}$ must be perpendicular to both $\vec{v}$ and $\vec{B}$. This result is important because it implies that magnetic fields can only change the direction of a charged particle's velocity, not its speed.

PSS 27.1: Magnetic Forces

Learning Goal:
To practice Problem-Solving Strategy 27.1: Magnetic Forces.

A particle with mass $1.81 \times 10^{-3}\ \mathrm{kg}$ and a charge of $1.22 \times 10^{-8}\ \mathrm{C}$ has, at a given instant, a velocity $\vec{v} = (3.00 \times 10^4\ \mathrm{m/s})\hat{j}$. What are the magnitude and direction of the particle's acceleration produced by a uniform magnetic field $\vec{B} = (1.63\ \mathrm{T})\hat{i} + (0.980\ \mathrm{T})\hat{j}$?

Problem-Solving Strategy 27.1: Magnetic Forces

IDENTIFY *the relevant concepts:*
The right-hand rule allows you to determine the magnetic force on a moving charged particle.

SET UP *the problem using the following steps:*

1. Draw the velocity vector $\vec{v}$ and magnetic field $\vec{B}$ with their tails together so that you can visualize the plane in which these two vectors lie.
2. Identify the angle ϕ between the two vectors.
3. Identify the target variables. This may be the magnitude and direction of the force, the velocity, or the magnetic field.

EXECUTE *the solution as follows:*

1. Express the magnetic force using the equation $\vec{F} = q\vec{v} \times \vec{B}$. The magnitude of the force is given by $F = qvB\sin\phi$.
2. Remember that $\vec{F}$ is perpendicular to the plane of the vectors $\vec{v}$ and $\vec{B}$. The direction of $\vec{v} \times \vec{B}$ is determined by the righthand rule. If q is negative, the force is opposite to $\vec{v} \times \vec{B}$.

EVALUATE *your answer:*
Whenever you can, solve the problem in two ways. Verify that the results agree.

IDENTIFY the relevant concepts

The problem asks for the acceleration of a moving charged particle. Since acceleration is related to force, you will need to determine the magnetic force acting on the particle.

SET UP the problem using the following steps

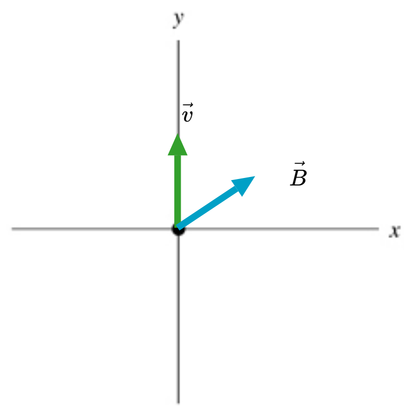
Part A

Draw the velocity $\vec{v}$ and magnetic field $\vec{B}$ vectors. Since they have different units, their relative magnitudes aren't relevant. Be certain they have the correct orientations relative to the given coordinate system. The dot in the center of the image represents the particle.

Recall that $\hat{i}$, $\hat{j}$, and $\hat{k}$ are the unit vectors in the *x*, *y*, and *z* directions, respectively.

ANSWER:

No elements selected



Correct

The strategy points out that there are two ways to solve problems with magnetic forces. In this problem, you already have the components of the vectors, so the cross product method will be much easier. This means that you do not need to find the value of ϕ, the angle between $\vec{v}$ and $\vec{B}$.

Also, note that the coordinate system in the vector drawing applet is two-dimensional. To make it three-dimensional, add a positive *z* axis oriented out of the screen.

EXECUTE the solution as follows

Part B

Find the acceleration vector for the charge.

Enter the *x*, *y*, and *z* components of the acceleration in meters per second squared separated by commas.

Hint 1. How to find cross products

Recall that the cross product distributes like a regular scalar product:

$$\vec{A} \times \left(\vec{B} + \vec{C}\right) = \vec{A} \times \vec{B} + \vec{A} \times \vec{C}$$

You will also need to use the following relations for products of unit vectors:

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

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

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

Finally, remember that the cross product of any vector with itself is zero. For example, $\hat{j} \times \hat{j} = 0$.

Hint 2. Find $\vec{v} \times \vec{B}$

Calculate $\vec{v} \times \vec{B}$, in terms of its components.

Enter the *x*, *y*, and *z* components of $\vec{v} \times \vec{B}$ in tesla meters per second separated by commas.

Hint 1. How to find cross products

Recall that the cross product distributes like a regular scalar product:

$$\vec{A} \times \left(\vec{B} + \vec{C}\right) = \vec{A} \times \vec{B} + \vec{A} \times \vec{C}$$

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Finally, remember that the cross product of any vector with itself is zero. For example, $\hat{j} \times \hat{j} = 0$.

ANSWER:

$\vec{v} \times \vec{B}$ = 0,0,−4.89×10^4 $\mathrm{T \cdot m/s}$

ANSWER:

$\vec{a}$ = 0,0,-0.330 $\mathrm{m/s^2}$

Correct

EVALUATE your answer

Part C

You can check your result by comparing its magnitude to the magnitude the acceleration would have if the particle's velocity had the same magnitude but it was perpendicular to the magnetic field.
Find the value of the expression qvB/m (the magnitude of $\vec{a}$ when $\vec{v}$ is perpendicular to $\vec{B}$), where q is the magnitude of the charge, v is the magnitude of the velocity, B is the magnitude of the magnetic field, and m is the mass of the particle.

Express your answer in meters per second squared.

Hint 1. Find the magnitude of the velocity

What is the value of v? Remember that the magnitude of a vector $v_x\hat{i} + v_y\hat{j} + v_z\hat{k}$ is given by

$$\sqrt{v_x^2 + v_y^2 + v_z^2}$$

Express your answer in meters per second squared.

ANSWER:

v = 3.00×10^4 $\mathrm{m/s^2}$

Correct

Hint 2. Find the magnitude of the magnetic field

What is the value of B? Remember that the magnitude of a vector $B_x\hat{i} + B_y\hat{j} + B_z\hat{k}$ is given by

$$\sqrt{B_x^2 + B_y^2 + B_z^2}$$

Express your answer in teslas.

ANSWER:

B = 1.90 T

ANSWER:

qvB/m = 0.385 $\mathrm{m/s^2}$

Correct

This quantity is of similar size to the magnitude of your answer from Part B. If you wanted to check precisely, you could find the value of ϕ and multiply the value you calculated above by $\sin\phi$. You would find that you had the same magnitude as the magnitude of the acceleration vector you found in Part B. Note that the magnitude of the magnetic force, and therefore the magnitude of the particle's acceleration, is at its maximum when $\vec{v}$ is perpendicular to $\vec{B}$, so it is not surprising that your answer to Part C is somewhat larger than the magnitude of the acceleration calculated in Part B.

To check the direction of your answer from Part B, use the right-hand rule. Point the fingers of your right hand parallel to $\vec{v}$ in your answer to Part A and then turn your wrist so that you can curl those fingers down toward $\vec{B}$. You will find that your thumb points into the screen, which is the negative *z* direction. Thus, your answer from Part B has the proper direction as well as the proper magnitude.

Exercise 27.1

A particle with a charge of -1.24×10^{-8} C is moving with instantaneous velocity $\vec{v}$ = (4.19 $\times$ 10^4 $\mathrm{m/s}$)$\hat{i}$ + (-3.85×10^4 $\mathrm{m/s}$)$\hat{j}$.

Part A

What is the force exerted on this particle by a magnetic field $\vec{B}$ = (2.60 T) $\hat{i}$?

Enter the x, y, and z components of the force separated by commas.

ANSWER:

F_x, F_y, F_z = 0,0,−1.24×10^{-3} N

Correct

Part B

What is the force exerted on this particle by a magnetic field $\vec{B}$ = (2.60 T) $\hat{k}$?

Enter the x, y, and z components of the force separated by commas.

ANSWER:

F_x, F_y, F_z = 1.24×10^{-3},1.35×10^{-3},0 N

Correct

Score Summary:

Your score on this assignment is 92.8%.

You received 92.81 out of a possible total of 100 points.