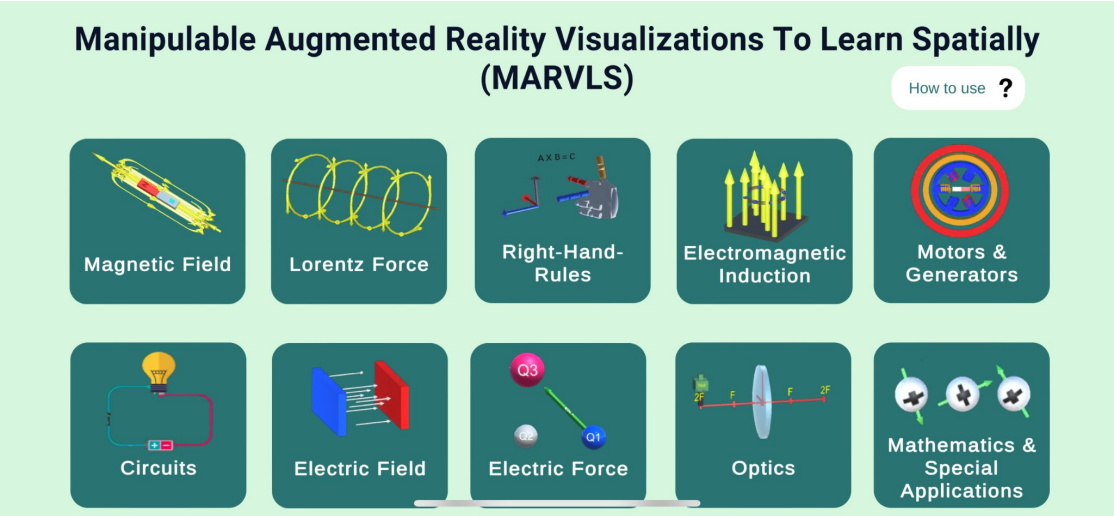
STANYS 2025 Conference Workshop



Magnetism Lessons

2D to 3D Representations

Materials

- Smartphone
- Merge Cube
- MARVLS AR for Physics 2
  to install: Scan QR Code below

App Store | Google Play | Merge Cube

SIENA

Contact: Michele McColgan (mmccolgan@siena.edu
Professor at Siena University and founder of MARVLS, LLC

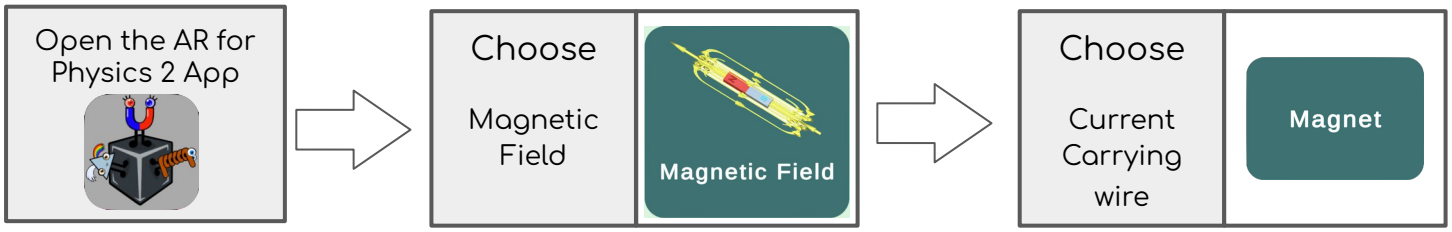
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MARVLS AR for Physics 2 - Magnetic Field of a Magnet

Learning Objective I can describe the magnetic field of a magnet.

MARVLS Navigation



- Look at the 3D model of the magnet. Draw the magnet and its magnetic field. Label the North (N) and South (S) ends of the magnet.

- What do you notice of about the **number** of field lines along the sides of the magnet?
- Is the **number** of field lines larger or smaller close to the ends of the magnet? What do you think this means?

- What do you notice about the **direction** of the field at the north pole? The south pole? Along the length?
- Where is the field the strongest? What do you think indicates the strength of the field?

The Biggest Magnet on the Earth

Have you ever thought about how the North Pole and South Pole got their names? The Earth has a magnetic field!



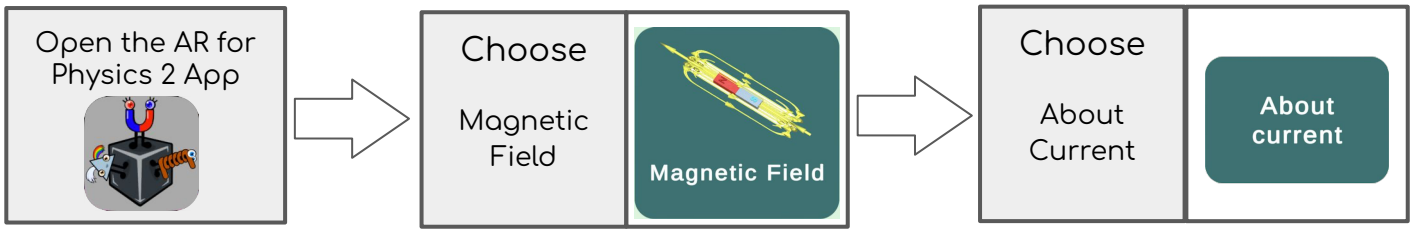
- Where is the earth's magnetic field strongest?
- Which way do the fields have to go to make a compass needle point toward the north geographic pole?
- Label on the bar magnet to the right the poles N and S..

ID: _____ **Date:** _____

MARVLS AR for Physics 2 - What is Current?

Learning Objective I can describe the difference between electron current and conventional current.

MARVLS Navigation



Current is charges moving along a wire. Scientists used to think those moving charges were positive charges. Current is defined as positive charges that move from high potential to low potential. Later, it was discovered that electron flow is how charge moves through a wire. The definition that current is positive charges remains.

Place the cube so the word MERGE is facing you.

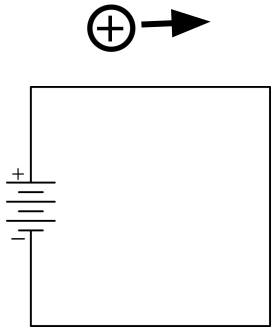


Click on the electrons checkbox. You're observing electron current. Draw what you see. Describe the current.

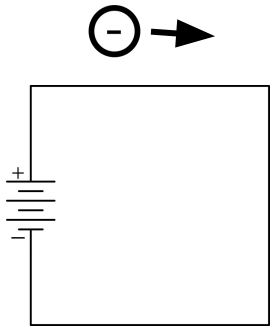
Click on the positive charges button. You're observing conventional current. Draw what you see. Describe the electron current.

In the circuit below, draw the positive charges moving clockwise (current) and the negative charges moving counter clockwise (electron flow). Use these symbols:

Draw conventional current:



Draw electron flow:

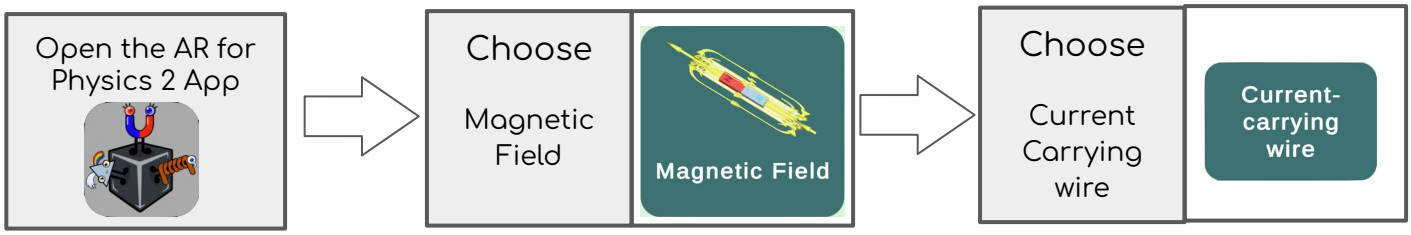


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MARVLS AR for Physics 2 - Magnetic Field of Long Wire

Learning Objective I can describe the magnetic field of a current-carrying wire.

MARVLS Navigation



Place the cube so the word MERGE is facing you.. You'll see a translucent wire.

Click on the Current on/off button. You're observing conventional current. What do you notice? Which way do the blue charges travel?

Rotate the model and view it from all directions, from different sides, from the top and from the bottom. Turn the cube upside down and see how the direction of the current and the field changes.



The arrows arranged in a circle around the wire represent the magnetic field of a current-carrying wire. Draw the current and magnetic field.

Describe the direction of the B-field vectors.

Describe what you notice about the difference between the length of the B-field vectors (arrows).

Describe the shape of the B-field vectors.

Learning Objective I can connect the 2D representation with the 3D model. I can create 2D representations of 3D models.

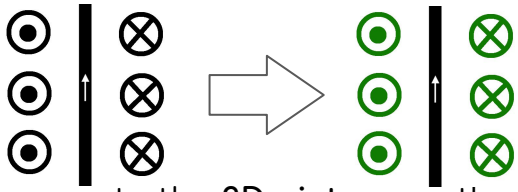
2D Representations and 3D Models

Click on the 2D button and make sure the current is on. Orient the cube so that the 2D image is facing you. Describe what you see on the 2D images (front and back).

Draw the 2D image that you see in the 3D model. Then rotate the cube and draw the image that is on the back.

Front	Back

Click on the ? in the bottom right corner of the screen. The 2D image is a button. Hold and press the button.



What happens to the **2D picture** on the button when you press and hold it?

Rotate the model as you press and hold the button. Describe what you notice about the **vectors** in the 3D model when you press and hold the button. How are the ⊙'s in the 2D image related to the B field vectors? The ⊗'s?

Press Axes and notice the coordinate system added to the scene. The positive direction for each direction is labeled with x, y, or z in the 3D model.

Press x. Draw the current, the green arrows when the button is pressed, and the the +x and -x vectors.

Which direction are the vectors represented by the ⊙s the ⊗s?

Press y. Draw the current, the green arrows when the button is pressed, and the the +y and -y vectors.

Which direction are the vectors represented by the ⊙s the ⊗s?

Learning Objective	I can describe the magnetic field of a loop of wire using the right-hand-rule.

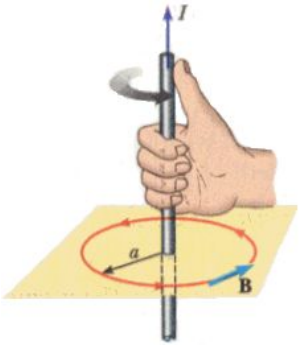
Right-Hand-Rule (RHR)

There are a few right-hand-rules to determine the direction of the magnetic field of a current-carrying wire. The picture to the right shows that if you point your thumb in the direction of the current, and you curl your fingers around a wire, the magnetic field circles around the wire.

Hold the cube so the word MERGE is facing you. You'll see a translucent wire above the cube.







Make sure the current is on. Point the thumb of your right hand in the direction of the current. Wrap your fingers around the wire in the 3D model. Click on the RHR button. Does your RHR gesture match up with the RHR gesture in the model? Draw the 3D model AND your right-hand-rule.

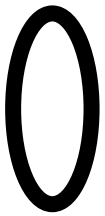
Turn the cube around so that the current is moving **downward**. Point the thumb of your right hand in the direction of the current. Wrap your fingers around the wire in the 3D model. Does the RHR match up with the direction of the magnetic field? Draw the 3D model AND your right-hand-rule.

Learning Objective I can describe the magnetic field of a magnet and a loop of wire using the RHR and 2D representations.

Magnetic Field of a Current-Carrying Loop

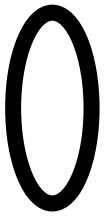
Does a loop of wire always produce a magnetic field? Take a look at the 3D model of the loop (refer to the AR model below). When does the magnetic field appear? Disappear?

For the loop to the right, draw the magnetic field of the loop in 3D for the case of the current traveling **down** the loop in the side closest to you. Label the direction of the current flow.



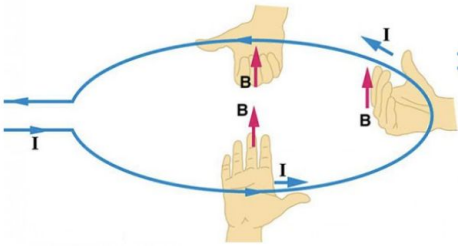
The right side of the loop is closest to you

For the loop to the right, draw the magnetic field of the loop in 3D for the case of the current traveling **up** the loop in the side closest to you. Label the direction of the current flow.



The right side of the loop is closest to you

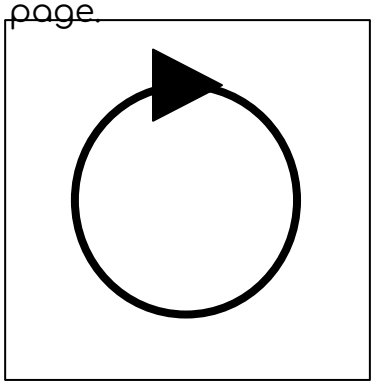
Use the RHR applied to small segments of the loop to map the magnetic field of the loop

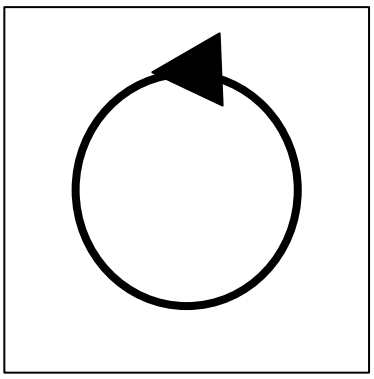


Now, press RHR and draw the 2D representations of the magnetic field loops below for current in the direction of the arrow. Use these two 2D symbols to represent the magnetic field into and out of the page.

out of the page: ⊙

into the page: ⊗

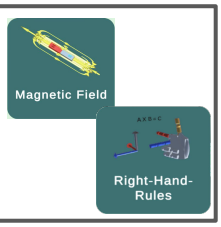


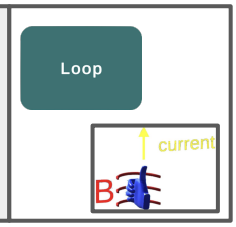


*Need help? Check out the loop model and RHR model using the navigation below and check your RHR gesture.

MARVLS Navigation

Open the AR for Physics 2 → Choose Magnetic Field or RHR → Choose Loop or current





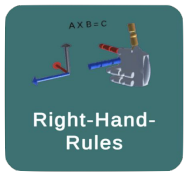
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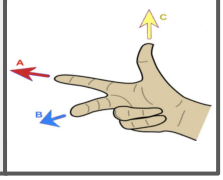
MARVLS: AR for Physics 2 - Right-Hand-Rules

Learning Objective I can use the right-hand-rule (RHR) to determine the direction of vectors that are determined from the cross product.

MARVLS Navigation

Open the AR for Physics 2 App 

→ Choose Right Hand Rules 

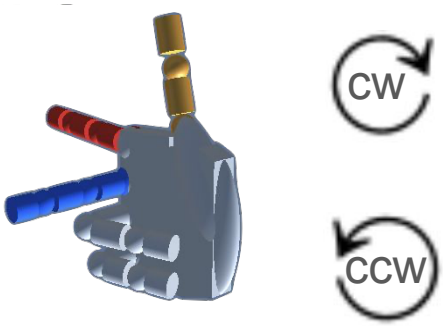
→ Choose R-H-R 

Place the cube so the word MERGE is on side of the cube facing you. Orient your hand and fingers to match the hand and fingers in the 3D model. 

Click on the **A** button. Point your pointer finger in the direction of A.

Click on the **B** button. Point your middle finger in the direction of B.

Click on the **C** button. Point your thumb in the direction of C.



Next, press and hold each of the variables, A, B, and C in the equation. $\vec{A} \times \vec{B} = \vec{C}$

In the 3D model, what three things are highlighted when the A button is pressed?

In the 3D model, what three things are highlighted when the B button is pressed?

In the 3D model, what three things are highlighted when the C button is pressed?

For the questions below, rotate your RHR hand gesture as you would rotate the hand above

Rotate the 3D model counter-clockwise(ccw) so the middle finger (blue) points down. What direction is C?

Rotate the 3D model ccw so the middle finger points to the right. What direction is C?

Now rotate the hand cw so the pointer (red) points to the right. What happens to B?

Rotate the 3D model ccw so the pointer points toward you. What happens to B?

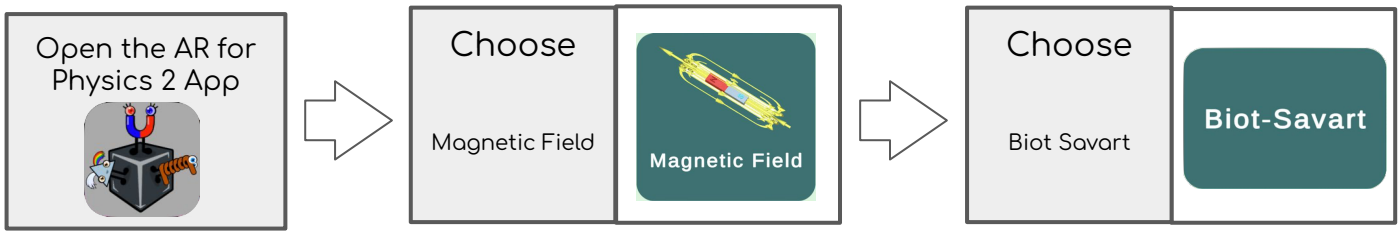
Rotate the thumb ccw to the left, what direction does you middle finger (blue) point?

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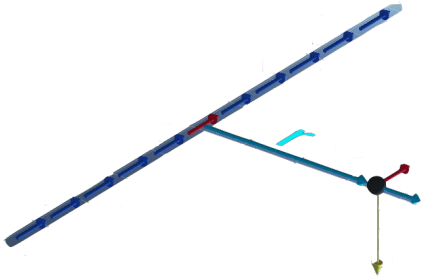
MARVLS AR for Physics 2 - Biot Savart Law

Learning Objective I can use the RHR to determine the direction of the B field at a point due to a moving charge or a current segment of wire.

MARVLS Navigation



The magnetic field due to a moving charge or current segment follows the Biot-Savart equation. The Biot-Savart law is a generalized solution of the magnetic field of a finite wire. It takes into account the magnetic field due to each small segment of current or moving charge in the wire and how that contributes to the magnetic field at any point around the wire.



$$d\vec{B} = \frac{\mu_0 I}{4\pi}\frac{d\vec{l} \times \hat{r}}{r^2}$$

Click on the question mark in the lower right corner of the screen. You will see the screen with the equation and boxes beneath the equation. Each of the boxes is labeled with a vector variable in the equation. The non-vector variables can be ignored when determining the direction of the B field. Press and hold each of the buttons to identify the vectors in the 3D model.

$d\vec{l}$ is the length of the current segment. What color is it?

$\hat{r}$ is the direction vector for $\vec{r}$. What color is it?

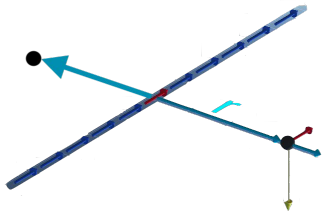
$\vec{B}$ is the magnetic field. What color is it?

Use the right-hand-rule and the buttons for the variables to verify the direction of the B field located at a distant position from the wire.

Point your pointer finger in the direction of $d\vec{l}$

Point your middle finger in the direction of $\hat{r}$

Point your thumb in the direction of the $\vec{B}$



Using the RHR and the equation, determine the direction of the B field at the dot on the other side of the wire.

What is the direction of $\vec{B}$?

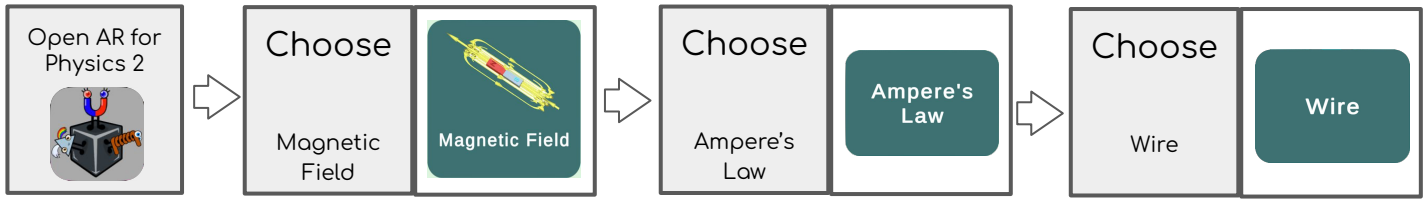
Note: $\hat{r}$ s the direction of the $\vec{r}$ vector located a distance r away from the wire.

ID: _____ **Date:** _____

MARVLS AR for Physics 2 - Ampere's law- outside wire of current

Learning Objective	I can connect the variables in Ampere's Law to a 3D model of the magnetic field outside of a current-carrying wire.

MARVLS Navigation



Ampere's Law connects the magnetic field around a closed loop to the current enclosed within the loop. The equation on the left is the integral around the closed loop. The dot product requires that B is is in the same direction as the path along the loop. The equation on the right requires that the current is enclosed within the loop.

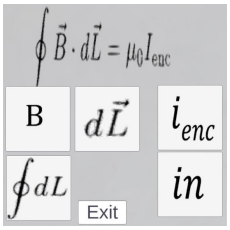
$$\oint \mathrm{B} \cdot \mathrm{ds} = \mu_0 \mathrm{i}_{\mathrm{enc}}$$



Orient the cube so that the word MERGE is on the front side of the cube.

In the App, click on the question mark in the lower right corner of the screen. Make sure the word "in" is visible. You will see the screen with the equation and boxes beneath the equation. Each of the boxes is labeled with a vector variable in the equation. Press and hold each of the buttons to identify the vectors in the 3D model.

Draw the model and label each of the variables and their directions.



To connect the variables of the equation to the 3D model, do the following:

Remember that the magnetic field is directed in a circle around the wire (refer to the long wire AR model if you need a refresher) . Click and press the variable B, what color is it (when it's not green)? What direction is it (CW or CCW) when viewed from above? The magnetic field is a constant at each point on the loop. It can be pulled out of the integral. What is the length of the circumference of a circle?

$\oint \mathrm{B} \cdot \mathrm{ds} =$ B 2π r = $\mu \mathrm{i}_{\mathrm{enc}}$ Solve for an equation for B =

Click on the variable dL and describe dL. What's the difference between dL and $\oint dL$? What color is $\oint dL$?

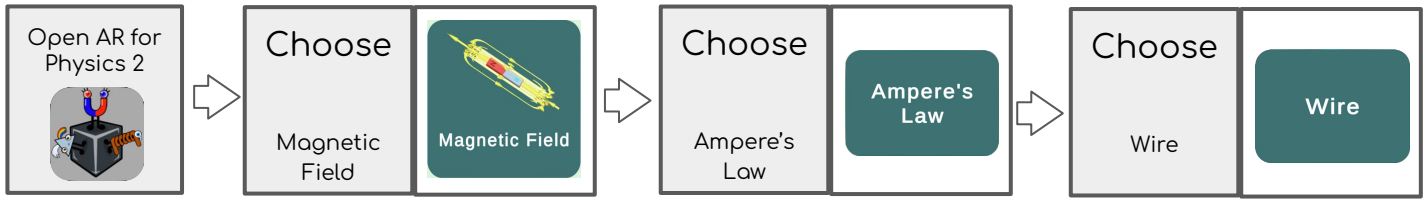
What is the direction of i_{enc}? Does it match with the right-hand-rule?

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MARVLS AR for Physics 2 - Ampere's law- inside wire of current

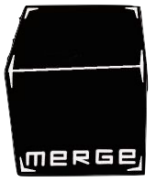
Learning Objective	I can connect the variables in Ampere's Law to a 3D model of the magnetic field inside of a current-carrying wire.

MARVLS Navigation



In this AR example, we zoom inside a current-carrying wire. We consider the magnetic field inside the wire due to a small cross section of the current inside the loop. Orient the cube so that the word MERGE is on the front side of the cube.

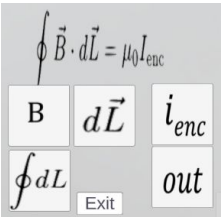
$$\oint \mathrm{B} \cdot \mathrm{ds} = \mu_0 \mathrm{i}_{\mathrm{enc}}$$



Notice in the model that the outside portion of the wire is translucent and the Amperian loop is inside the wire and enclosing only a portion of the current flowing through the wire.

In the App, click on the question mark in the lower right corner of the screen. Make sure the word "out" is visible. Press and hold each of the buttons to identify the vectors in the 3D model.

Draw the model and label each of the variables and their directions.



In this example, the *total* current in the wire is NOT enclosed within the loop. We need to represent the amount of current enclosed using the current density, given by the vector **J**.

To accurately determine the current enclosed by the loop, we use the equation

$$J = \frac{I}{\pi r^2}$$ where r is the radius of the Amperian loop. Try substituting $I_{enc}=J\pi r^2$ and solving for the magnetic field inside of a current-carrying wire.

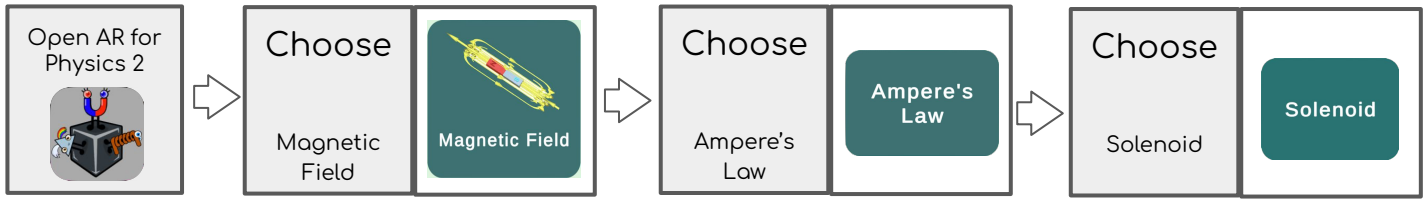
B =

ID: _____ Date: _____

MARVLS AR for Physics 2 - Ampere's law- solenoid

Learning Objective I can connect the variables in Ampere's Law to a 3D model of the magnetic field of a solenoid.

MARVLS Navigation



In this model, look closely at how the Amperian loop is drawn in the AR model. The loop is drawn on the side of solenoid so that the loops of current go through the Amperian loop!

$$\oint \mathrm{B} \cdot \mathrm{ds} = \mu_0 \mathrm{i}_{\mathrm{enc}}$$

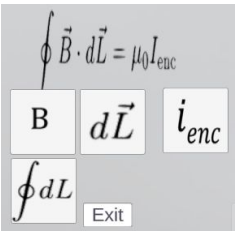


Orient the cube so that the word MERGE is on the front side of the cube.

Click on the question mark in the lower right corner of the screen. Press and hold each of the buttons to identify the vectors in the 3D model.

Because we're drawing our Amperian loop around the side of the solenoid so the loops of wire go through the Amperian loop, we need to represent the number of loops of current as N.

Draw the model and label each of the variables.



The magnetic field of the solenoid is a constant inside the solenoid and pointed upward with the coils of wire wrapped around it. Notice that the magnetic field is zero outside the solenoid. **This means that there are 3 sides of the loop where the magnetic field is zero.** So, while there is a closed loop, there's only one side of the square Amperian loop with a magnetic field that points in the same direction.

To determine the enclosed current for a sheet of current, use that fact that each coil of wire has a current, I. And there are N coils. So multiply them together to find:

$$I_{enc} =$$

What equation can we use for the length around a square wire if we say each side of the square is L? Only one side is in the same direction as B. From these equations, calculate B.

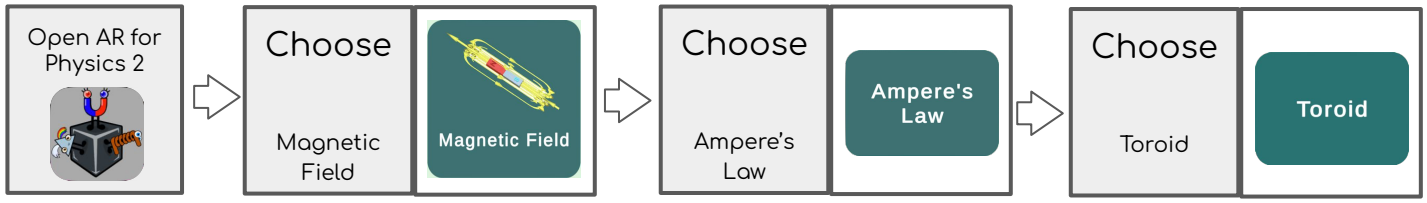
$$B =$$

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MARVLS AR for Physics 2 - Ampere's law- toroid

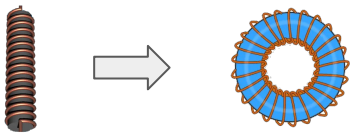
Learning Objective	I can connect the variables in Ampere's Law to a 3D model of the magnetic field of toroid.

MARVLS Navigation



Look closely at the toroid AR model. Notice that the Amperian loop is drawn inside the hollow donut. We can connect the toroid to a solenoid if we imagine bending the solenoid into a circle.

$$\oint \mathrm{B} \cdot \mathrm{ds} = \mu_0 \mathrm{i}_{\mathrm{enc}}$$



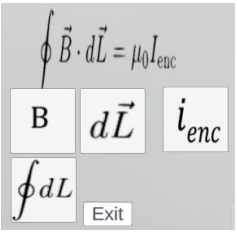


Orient the cube so that the word MERGE is on the front side of the cube.

Click on the question mark in the lower right corner of the screen. Press and hold each of the buttons to identify the vectors in the 3D model.

The Amperian loop is inside the toroid and it encloses all of the loops of wire carrying current.

Draw the model and label each of the variables.



The magnetic field of the toroid is parallel to a circle inside of the toroid. The Amperian loop is in the shape of a circle and the path is in the same direction as the magnetic field.

The magnetic field is a constant at each point on the loop. It can be pulled out of the integral. What is the length of the circumference of a circle? We can set $\oint dL$ equal to the circumference:

$$\oint dL =$$

To determine the enclosed current for the coil around the toroid, multiply N times I. So multiply them together to find:

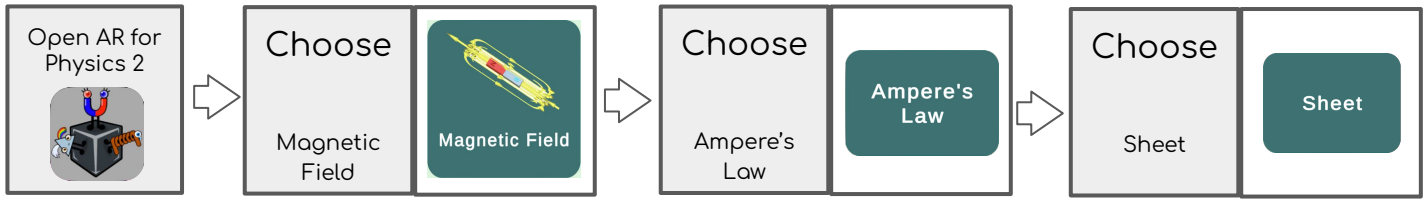
I_{enc} = and B =

ID: _____ Date: _____

MARVLS: Physics II E&M - Ampere's law- sheet of current

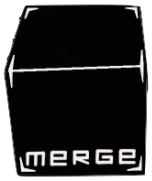
Learning Objective	I can connect the variables in Ampere's Law to a 3D model of the magnetic field of a sheet of current.

MARVLS Navigation



In this model, look closely at how the Amperian loop is drawn in the AR model. The arrows in the sheet represent the current. Those arrows go through the face of the loop.

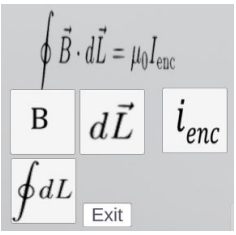
$$\oint \mathrm{B} \cdot \mathrm{ds} = \mu_0 \mathrm{i}_{\mathrm{enc}}$$



Orient the cube so that the word MERGE is on the top side of the cube.

Click on the question mark in the lower right corner of the screen. Press and hold each of the buttons to identify the vectors in the 3D model.

Draw the model and label each of the variables. Because we're drawing our Amperian loop around part of the sheet, we need to use the current density, K.



Why do you think there are only two vectors for the B field? If you use the RHR to determine the direction of the magnetic field for each of the current arrows, what happens to the B field on top and bottom? Why do you think they cancel?

To determine the enclosed current for a sheet of current, use the equation K = I/L

$$I_{enc} =$$

What equation can we use for the length around a square wire if we say each side of the square is L? Only two sides are in the same direction as B. From the equations, calculate B.

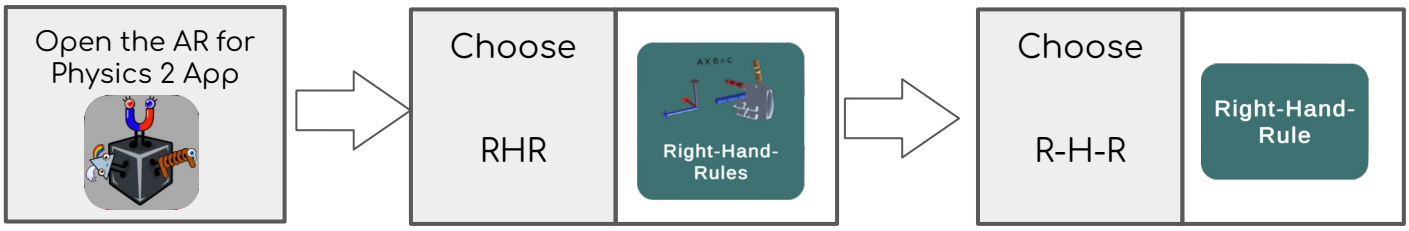
$$B =$$

ID: _____ Date: _____

MARVLS AR in Physics 2 - Right-Hand-Rule

Learning Objective I can use the right-hand-rule to determine the direction of vectors that are are determined from the cross product.

MARVLS Navigation

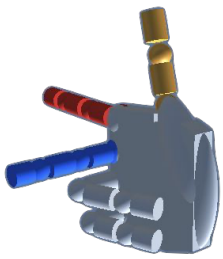


Place the cube so the word MERGE is on side of the cube facing you. Orient your right hand and fingers to match the hand and fingers in the 3D model.

Click on the **A** button. Point your pointer finger in the direction of A.

Click on the **B** button. Point your middle finger in the direction of B.

Click on the **C** button. Point your thumb in the direction of C.



Rotate the 3D model so the middle finger (blue) points down. What happens to C?

Rotate the 3D model so the middle finger points to the right. What happens to C?

Next, press and hold each of the variables, A, B, and C in the equation.

$$\vec{A} \times \vec{B} = \vec{C}$$

In the 3D model, what three things are highlighted when the A button is pressed?

In the 3D model, what three things are highlighted when the B button is pressed?

In the 3D model, what three things are highlighted when the C button is pressed?

Practice rotating *your* hand for each of these examples.

Now rotate the hand so the pointer points to the right. What happens to B?

Rotate the 3D model so the pointer points toward you. What happens to B?

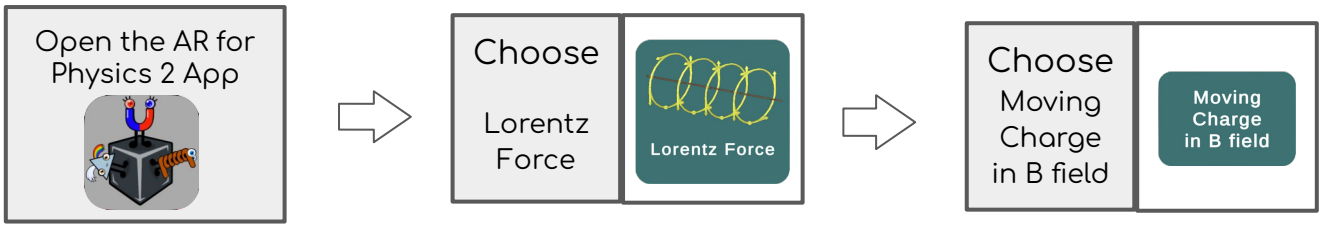
If your thumb points to the left, what direction does you middle finger point?

ID: _____ **Date:** _____

MARVLS AR in Physics 2 - Lorentz Force and the RHR

Learning Objective I can use the RHR to determine the direction of the force acting on a moving charge in a magnetic field.

MARVLS Navigation



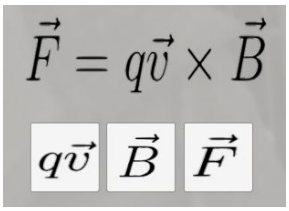
The Lorentz Force model is a snapshot of a moving positively charged particle in a magnetic field. The model shows the force on the charged particle, the Lorentz force equation and how it relates to the model, and 2D representations in the model.

$$\mathbf{F} = q\mathbf{v} \times \mathbf{B}$$

Orient the cube so that the word MERGE is facing you.



Click on the question mark in the lower right corner of the screen. You will see the screen with the equation and boxes beneath the equation. Each of the boxes is labeled with a vector variable in the equation. Press and hold each of the buttons to identify the vectors in the 3D model.



Use your right hand and the right-hand-rule and the buttons for the variables to verify the direction of the force vector. To do this, do the following:

Point your pointer finger in the direction of the velocity $\vec{v}$.

Point your middle finger in the direction of the magnetic field $\vec{B}$.

Point your thumb in the direction of the force $\vec{F}$.

Does the direction your thumb is pointing match the direction of the force in the AR model?

Next, turn the cube so that the word MERGE is on the right. Try the process again. Point your pointer finger in the direction of the velocity, your middle finger in the direction of the magnetic field (B). Does your thumb match the direction of the force?

Let's try one more. Next, turn the cube so that the word MERGE is the side facing you. Point your pointer finger in the direction of the velocity, your middle finger in the direction of the magnetic field (B). Does your thumb match the direction of the force?

Rotate the cube in a different direction and try again. Keep trying until you can quickly match your RHR to the AR model.

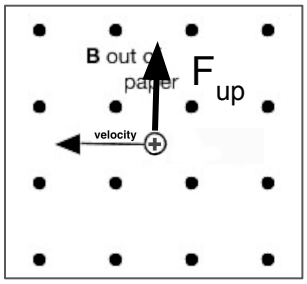
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MARVLS AR in Physics 2 - Lorentz Force 3D Models and 2D Representations

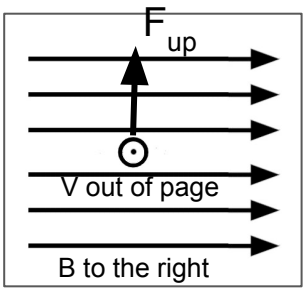
Learning Objective	I can create 2D representations of a 3D AR model.

Two examples of 2D representations of the positive charge moving in a magnetic field and the resultant force on that charge are included in the model. These are shown below.

1



2

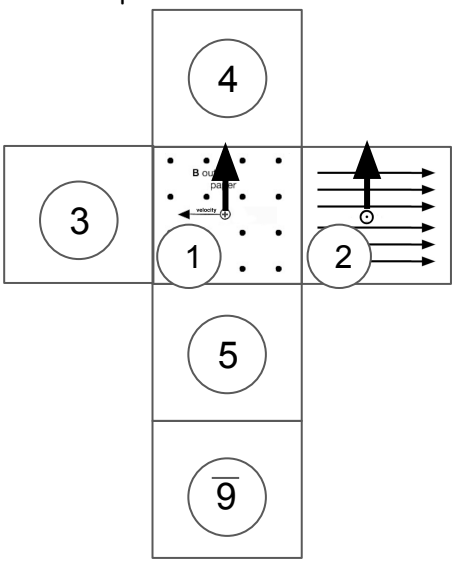




In the App, orient the cube so that the word MERGE is on the side of the cube and you can see the model and both 2D representations. Create four of the missing 2D representations. Use the template to the right and draw the 2D representations for the pictures in 3, 4, 5, and 6. Note that 6 is upside down in the template.

3

4



5

6

ID: _____ Date: _____

MARVLS AR in Physics 2 - Lorentz Force - Motion of Charge in Magnetic Field

Learning Objective I can predict the direction of motion for a moving charge in a magnetic field.

MARVLS Navigation

Open the AR for Physics 2 App



Choose Lorentz Force





Choose Circular Path



This Lorentz Force model shows how a moving charged particle changes direction as it moves in a magnetic field. The charged particle changes direction based on whether the charge is a positive charge or a negative charge.

$$\mathbf{F} = q\mathbf{v} \times \mathbf{B}$$

Case 1: B out + charge RHR

Click on next a few times to see how the positive charge moves in the magnetic field. Then draw the charge at 3 locations. Draw the force and the velocity vectors.

What do you notice about how the force and velocity vectors change? Check it with your RHR.

Case 3: B in + charge RHR

Click on next a few times to see how the positive charge moves in the magnetic field. Then draw the charge at 3 locations. Draw the force and the velocity vectors.

What do you notice about how the force and velocity vectors change? Check it with your RHR.

Case 2: B out - charge RHR

Click on next a few times to see how the positive charge moves in the magnetic field. Then draw the charge at 3 locations. Draw the force and the velocity vectors.

What do you notice about how the force and velocity vectors change? Check it with your RHR.

Case 3: B in - charge RHR

Click on a few times to see how the positive charge moves in the magnetic field. Then draw the charge at 3 locations. Draw the force and the velocity vectors.

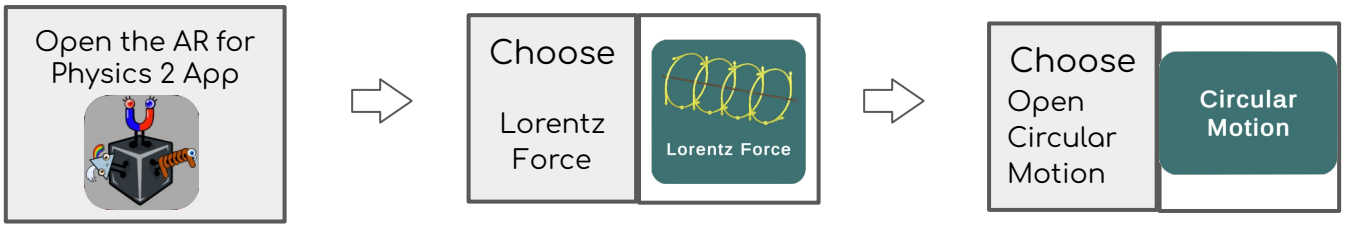
What do you notice about how the force and velocity vectors change?Check it with your RHR.

ID: _____ **Date:** _____

MARVLS AR in Physics 2 - Lorentz Force - Circular Motion - Strength of B field

Learning Objective For a charged particle moving in a magnetic field, I can predict how the radius changes when the strength of the magnetic field changes.

MARVLS Navigation



This Lorentz Force model shows how a moving charged particle moves in a circle in a magnetic field.

$$\mathbf{F} = q\mathbf{v} \times \mathbf{B}$$

Case 1: **small B**

Using your RHR, determine whether the charge is positive or negative.

Why does the charged particle move in a circle?

Case 2: **big B**

What's different about this case compared to the other case?

Using the Lorentz Force equation, explain why the change in the value of the radius is true.

How would the motion of the charge change if the direction of the magnetic field was pointed in the opposite direction? Can you rotate the MERGE cube for this case?

Draw the 2D representation for this case.

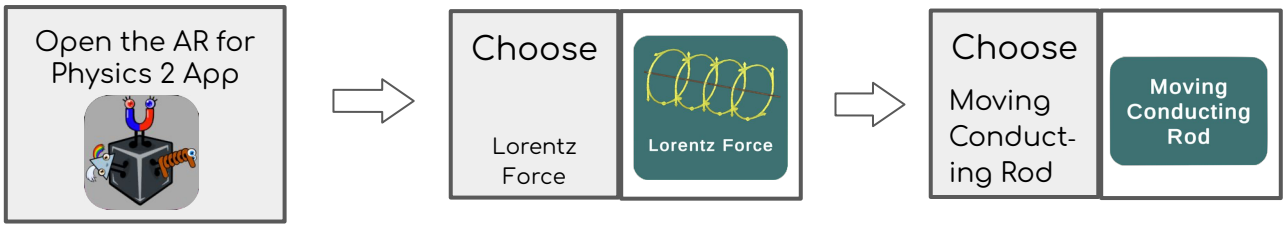
How would the motion of the moving charge change if the sign of the charge changed? Can you show in a drawing below with the vectors using your RHR? Feel free to look at an earlier AR model to help you.

ID: _____ Date: _____

MARVLS AR in Physics 2 - Lorentz Force - Motion of Charge in Conducting Rod

Learning Objective I can use the RHR to determine the direction of the B field at a point due to a current segment of wire.

MARVLS Navigation



In this model, a conducting rod is moved horizontally in a magnetic field. The Lorentz Force model can be used to think about how charges in the conducting rod move to create a separation of charge. And that separation of charge creates a voltage.

$$\mathbf{F} = q\mathbf{v} \times \mathbf{B}$$

Click on **Play** What happens as the conducting rod moves?

Using the RHR, which charges move up in the rod? Down?

Using the RHR, for EACH CHARGE draw the vectors on each of the charges. Show why the charges move in the direction they do.

Why aren't the charges moving in a circle in this example?

When there's a separation of charge, a change in potential is created. Can you draw how you'd connect a circuit to the rod to get current to flow?

What would you change about the model so that the separation of charge changes and current flows the other way? Is there more than one way to accomplish this?

ID: _____ Date: _____

MARVLS AR in Physics 2 - Magnetic Flux

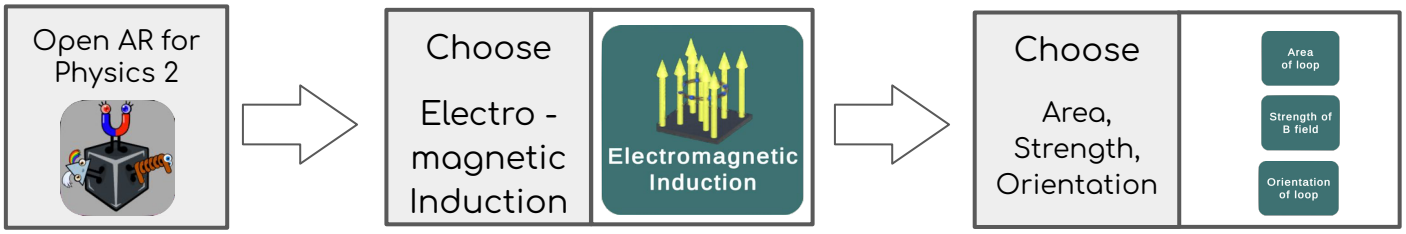
Learning Objective	I can describe how a change in area, magnetic field strength or orientation changes the magnetic flux.

Magnetic Flux is the magnetic field through the face of the loop. A change in the AREA, MAGNETIC FIELD STRENGTH, and ORIENTATION can all change the magnetic flux. In the three examples below the flux is given by the equation:

$$\Phi_B = \int \vec{B} \cdot d\vec{A}$$

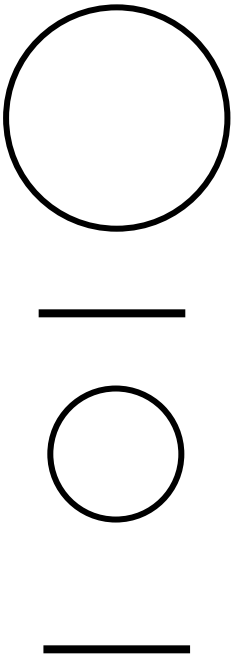


MARVLS Navigation



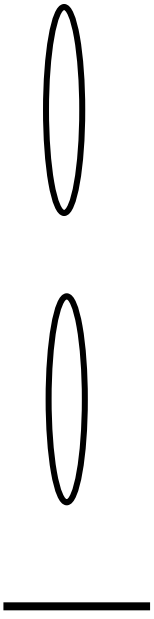
Area of loop

Draw the number of dots (2D representation of arrows coming at you) when the **area** is big and small. Write the number of arrows beneath each.



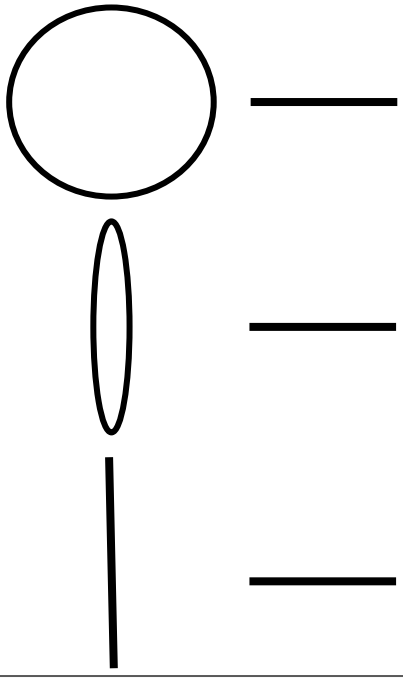
Strength of B field

View the AR model so you can see the length of the arrows. How does the **magnetic field strength** change (big and small). How much bigger are the large arrows than the small arrows (fill in the blank)?



Orientation of loop

Draw the number of dots (2D representation) for each **orientation** of the loop to the B field. Assume the B field is coming out the page. Enter the number of B field arrows on the line to the right for each case

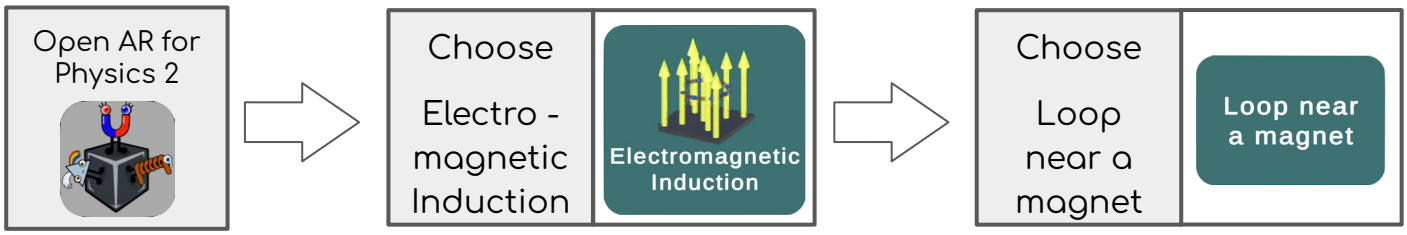


ID: _____ Date: _____

MARVLS AR in Physics 2 - Induced Current and Changing Magnetic Field

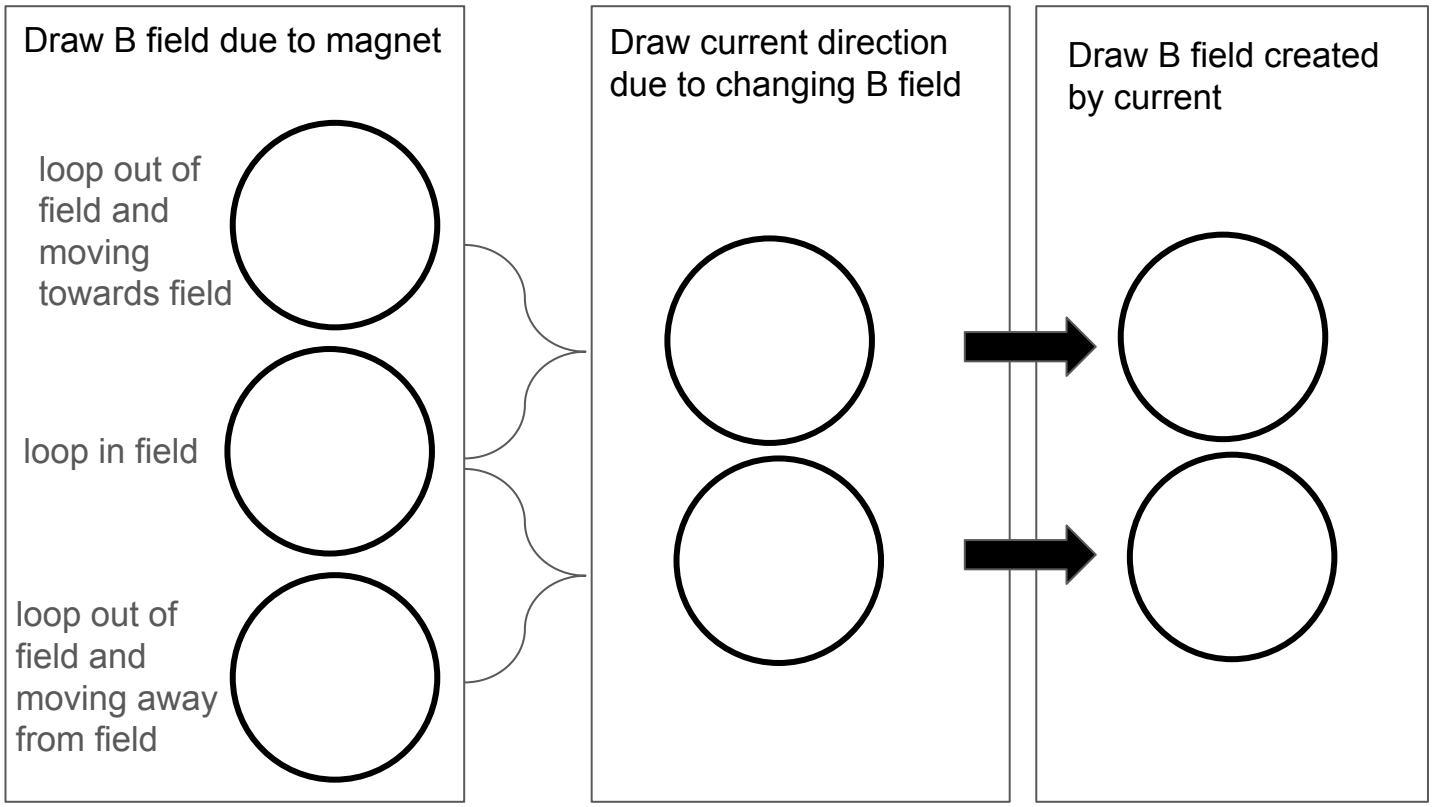
Learning Objective	I can describe the direction of the induced current when a loop is moved into and out of a magnetic field.

MARVLS Navigation



- In the circles on the left, draw the 2D representation of the magnetic field ***inside the loop*** (use dots, x's, or "no field") due to the B field of the magnet
- In the middle circles, draw the current that's induced in the loop due to the changing magnetic field (cw or ccw).
- In the circles on the right, draw the magnetic field created by the induced current(use dots, x's, or "no field").





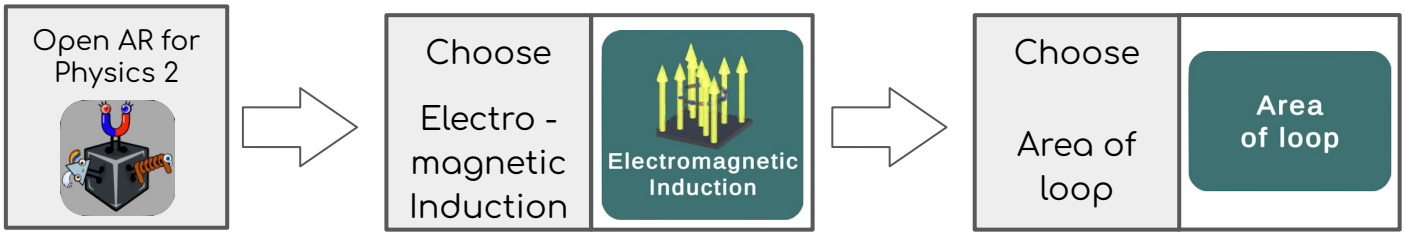
- What do you notice of about the **number** of field lines along the sides of the magnet?

ID: _____ Date: _____

MARVLS AR in Physics 2 - Induced Current and Changing Magnetic Field

Learning Objective I can describe the direction of the induced current when the area of the loop changes.

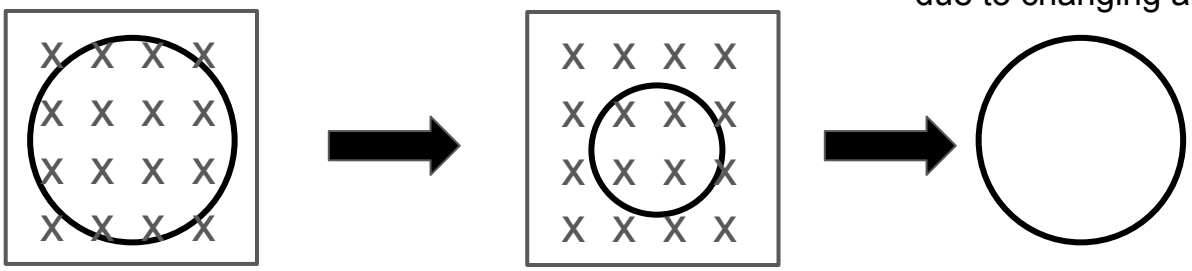
MARVLS Navigation



- For each of the examples of the area increasing or decreasing, indicate the direction of the current in the loop on the right.

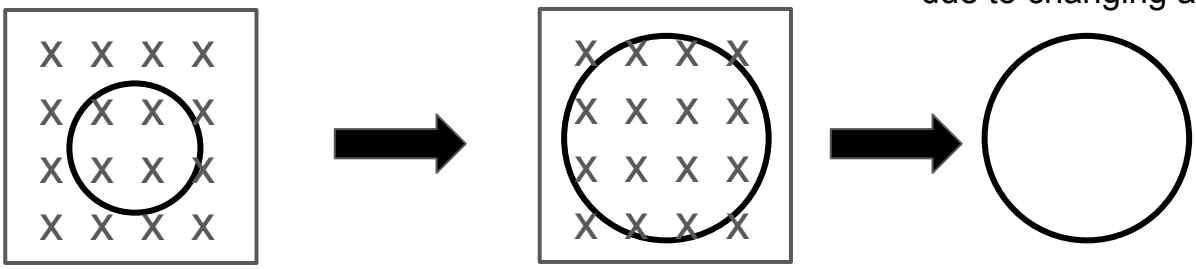
Area of loop decreases

Draw current direction due to changing area



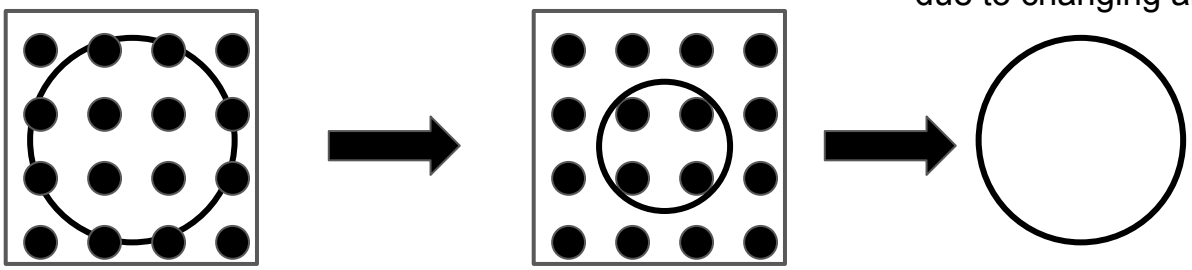
Area of loop increases

Draw current direction due to changing area

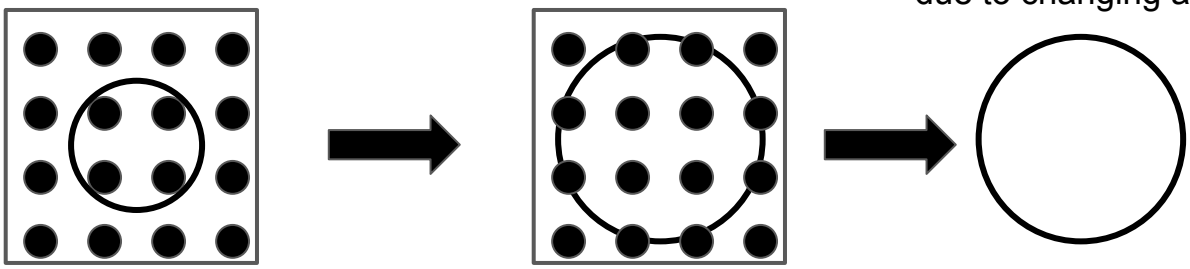


Area of loop decreases

Draw current direction due to changing area



Draw current direction due to changing area

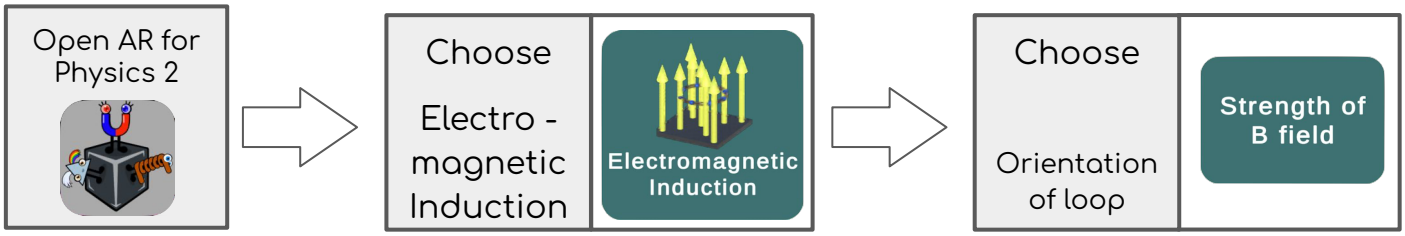


ID: _____ Date: _____

MARVLS AR in Physics 2 - Induced Current and Changing Magnetic Field

Learning Objective I can describe the direction of the induced current when the strength of the magnetic field changes.

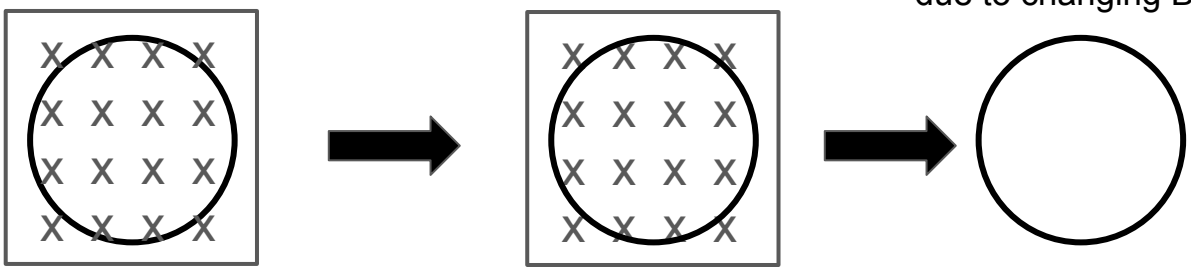
MARVLS Navigation



- For each of the examples of the magnetic field increasing or decreasing, indicate the direction of the current in the loop on the right.

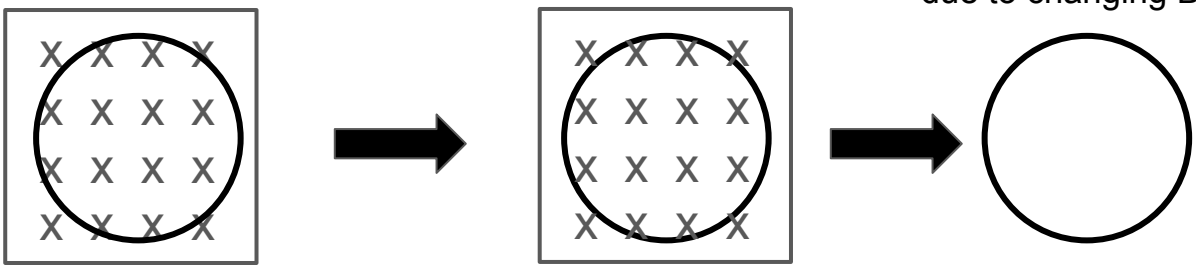
B field **decreases**

Draw current direction due to changing B field



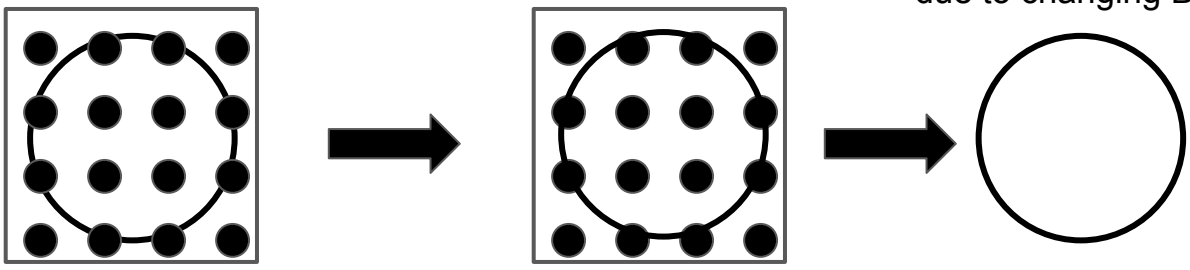
B field **increases**

Draw current direction due to changing B field



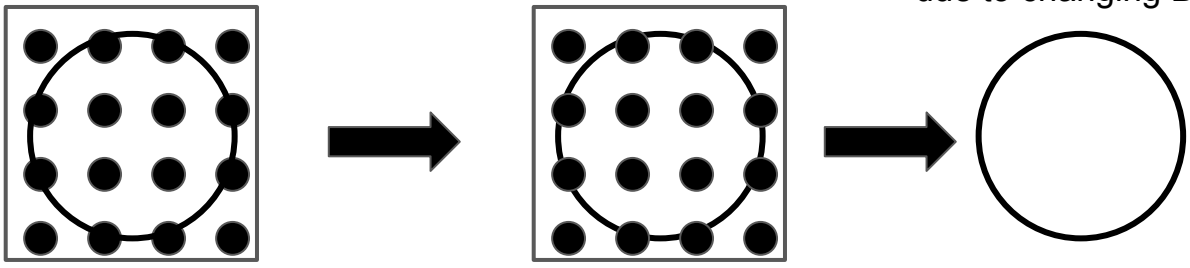
B field **decreases**

Draw current direction due to changing B field



B field **increases**

Draw current direction due to changing B field

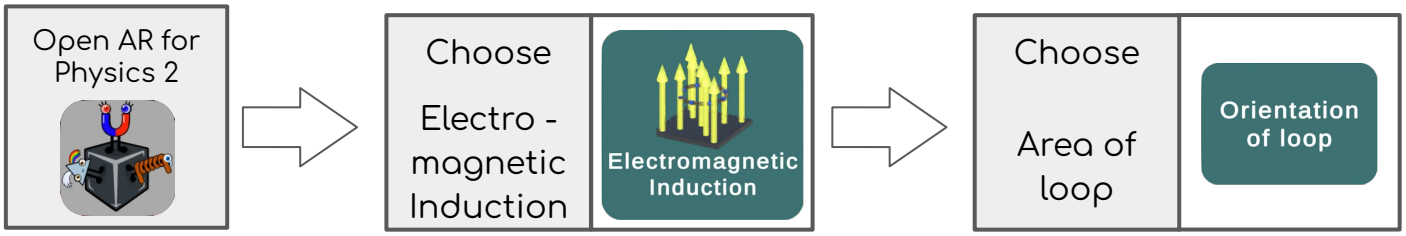


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MARVLS AR in Physics 2 - Induced Current and Changing Magnetic Field

Learning Objective I can describe the direction of the induced current when the orientation of the magnetic field to the area of the loop changes.

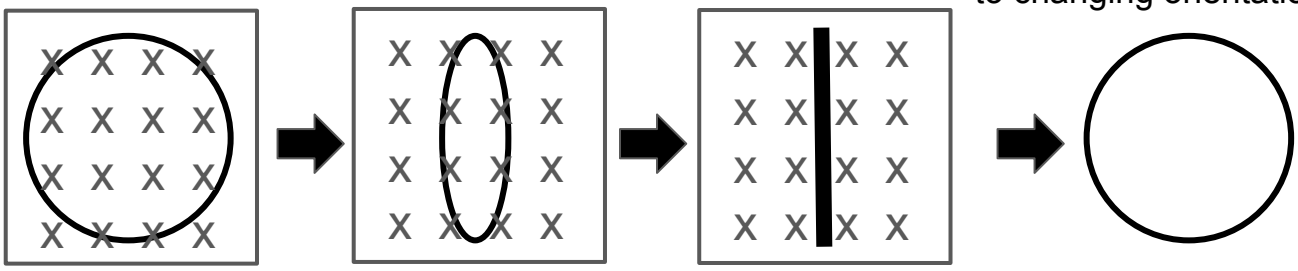
MARVLS Navigation



- For each of the examples of the changing orientation of the loop, indicate the direction of the current in the loop on the right.

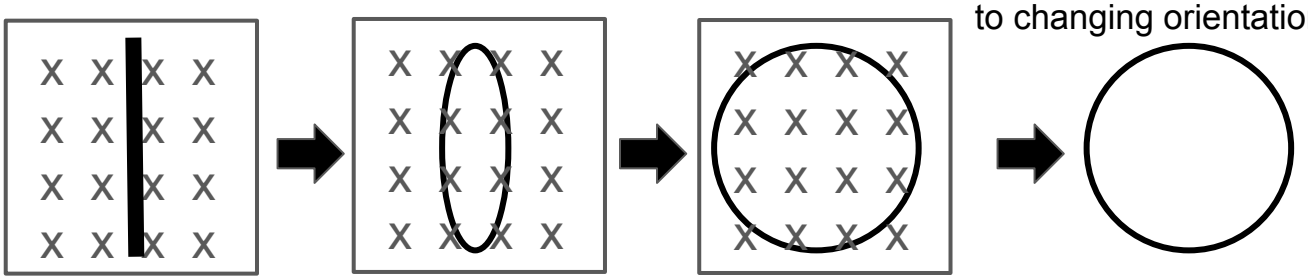
Rotate the loop **out** of the B field

Draw current direction due to changing orientation

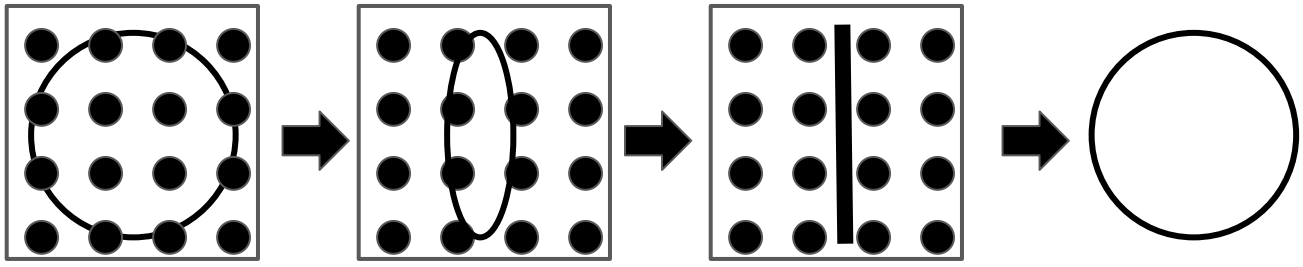


Rotate the loop **into** the B field

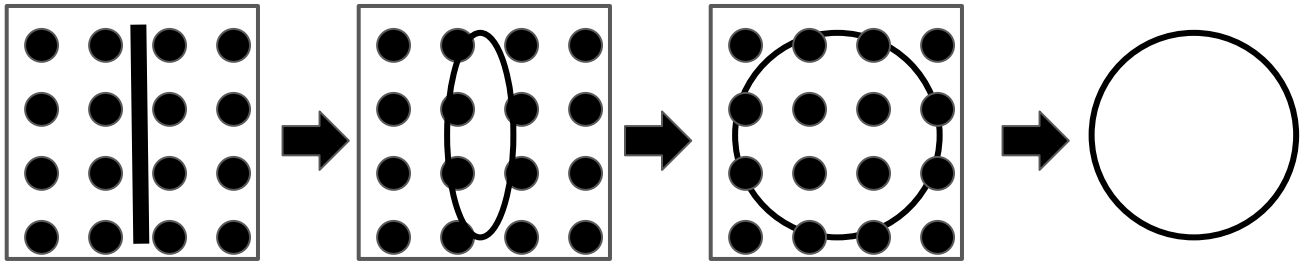
Draw current direction due to changing orientation



Rotate the loop **out** of the B field



Rotate the loop **into** the B field

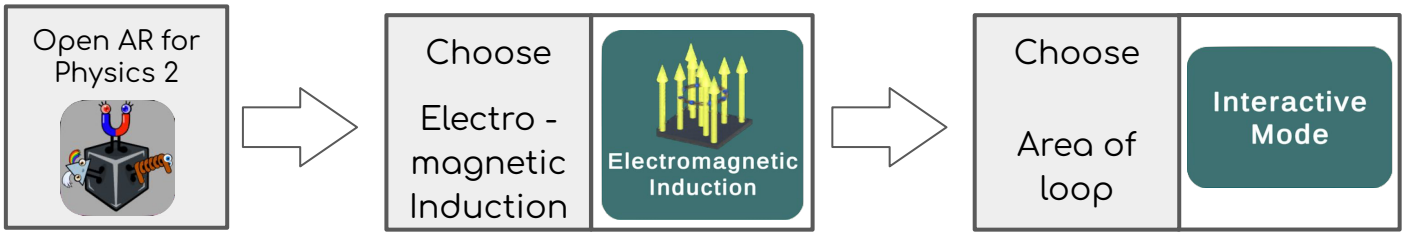


ID: _____ Date: _____

MARVLS AR in Physics 2 - Induced Current and Changing Magnetic Field

Learning Objective I can demonstrate the three ways to induce a current by changing the magnetic flux

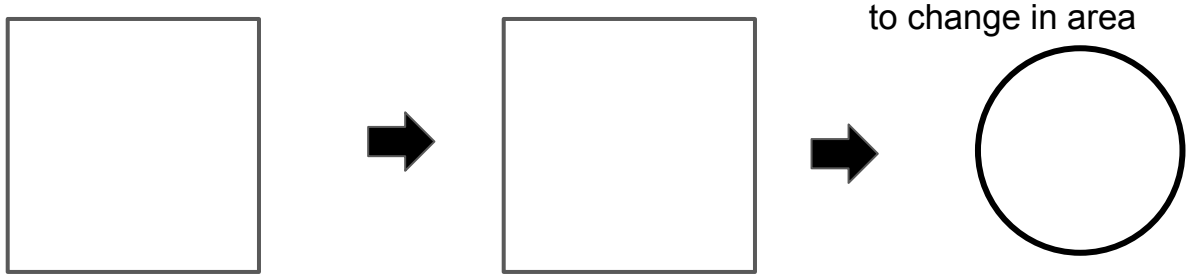
MARVLS Navigation



- Using the AR model, describe how you changed the **area of the loop** to induce a current. Draw 2D representations in the boxes to indicate the change and draw an arrow on the loop to indicate the direction of the current.

Change in flux due to change in area

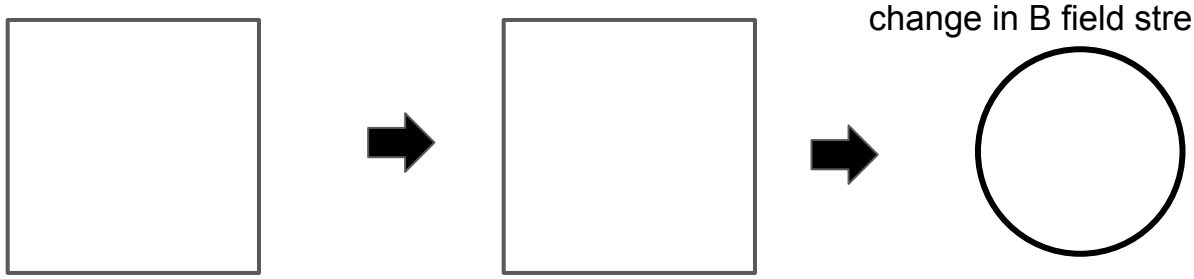
Draw current direction due to change in area



- Using the AR model, describe how you changed the **strength of the B field through the loop** to induce a current. Draw 2D representations in the boxes to indicate the change and draw an arrow on the loop to indicate the direction of the current.

Change in flux due to change in B field strength

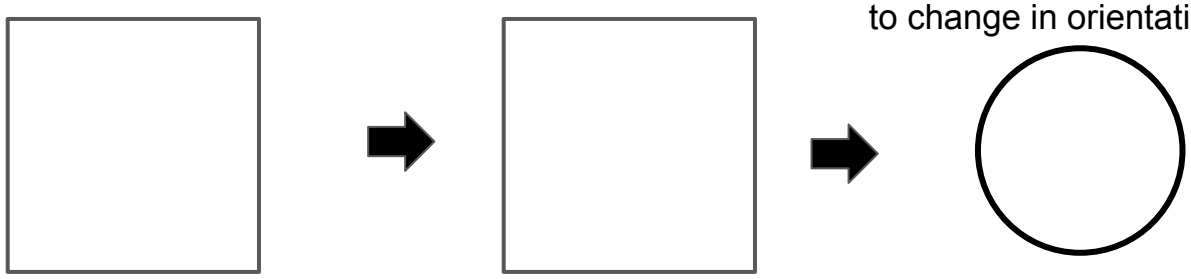
Draw current direction due to change in B field strength



- Using the AR model, describe how you changed the **orientation of the loop** to induce a current raw 2D representations in the boxes to indicate the change and draw an arrow on the loop to indicate the direction of the current.

Change in flux due to change in orientation

Draw current direction due to change in orientation

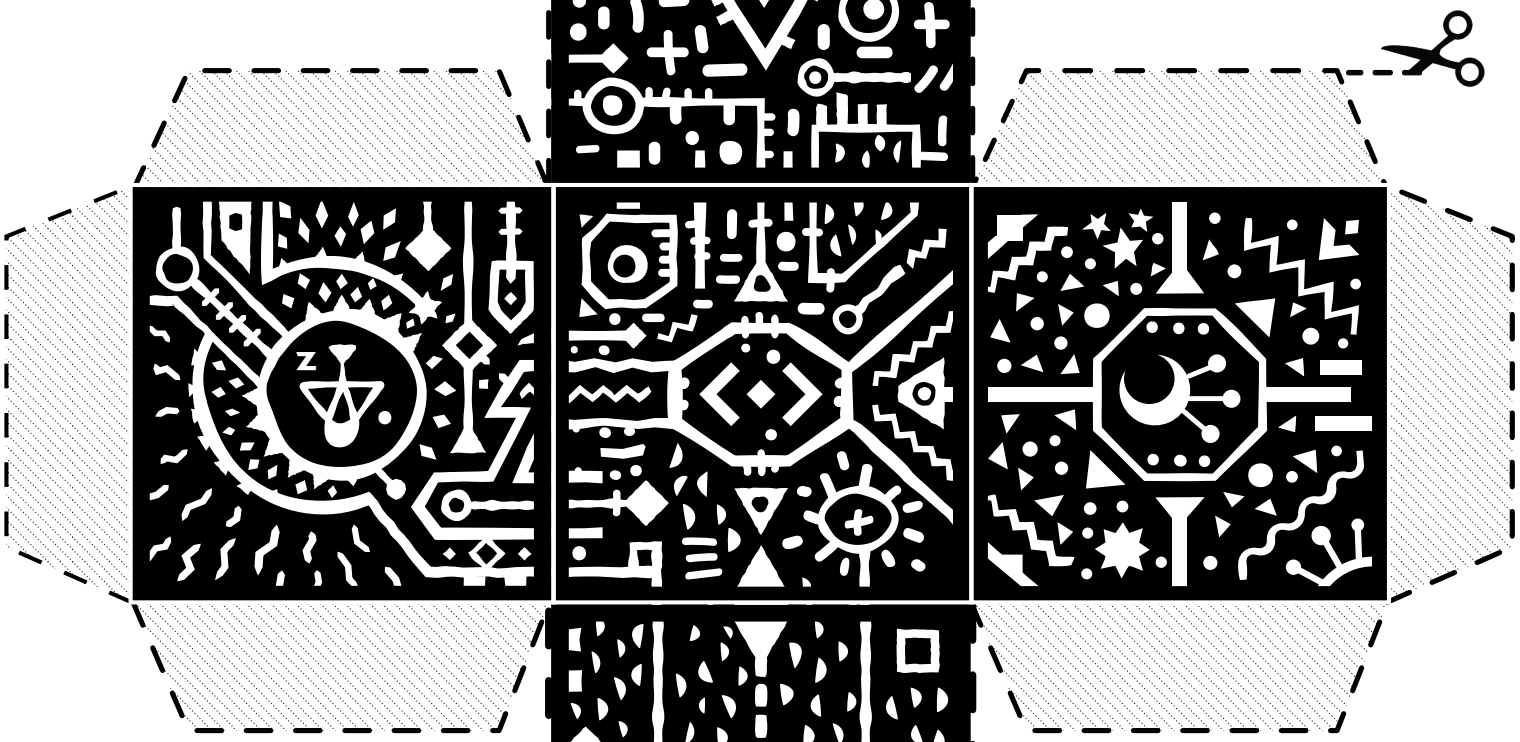


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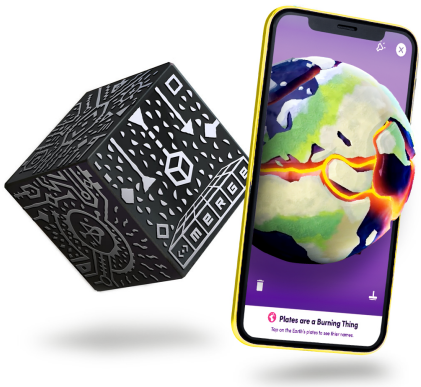
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