Electromagnetism – ID: 9463

By Peter Fox

Time required
45 minutes

Topic: Electricity and Magnetism

- *Describe the operation of AC and DC generators in terms of magnetic fields and induced emf and currents.*

Activity Overview

In this activity, students use an animated diagram of a magnetic field and a coil. Students rotate the coil and determine the number of magnetic field lines passing through the coil at a given angle. Students graph the relationship and then consider the "rate of change" of the magnetic field.

Materials

To complete this activity, each student will require the following:

- *TI-Nspire™ technology*
- *pen or pencil*
- *blank sheet of paper*

TI-Nspire Applications

Notes, Graphs & Geometry, Lists & Spreadsheet

Teacher Preparation

Before carrying out this activity, review with students how the three-dimensional situation of a coil rotating through a magnetic field can be represented in two dimensions. Students should also understand the relationship between the number of magnetic field lines in a region and the strength of the magnetic field in that region.

- *If possible, supplement this activity with an activity using physical magnetic generators. Encourage students to relate their observations of frequency of rotation, strength of magnetic field, and number of coils of wire back to this activity.*
- *The screenshots on pages 2–4 demonstrate expected student results. Refer to the screenshots on pages 5 and 6 for a preview of the student TI-Nspire document (.tns file).*
- ***To download the .tns file, go to education.ti.com/exchange and enter "9463" in the search box.***

Classroom Management

- *This activity is designed to be **teacher-led** with students following along on their handhelds. You may use the following pages to present the material to the class and encourage discussion. Note that the majority of the ideas and concepts are presented only in **this** document, so you should make sure to cover all the material necessary for students to comprehend the concepts.*
- *Students may answer the questions posed in the .tns file using the Notes application or on blank paper.*
- *In some cases, these instructions are specific to those students using TI-Nspire handheld devices, but the activity can easily be done using TI-Nspire computer software.*

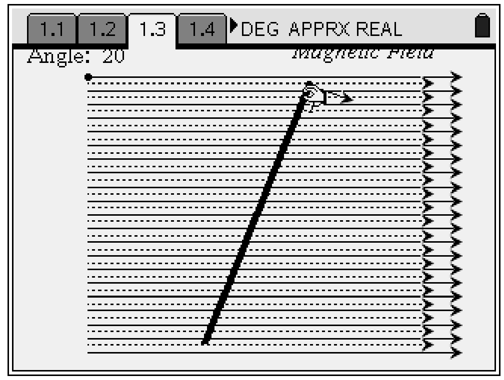
The following question will guide student exploration in this activity:

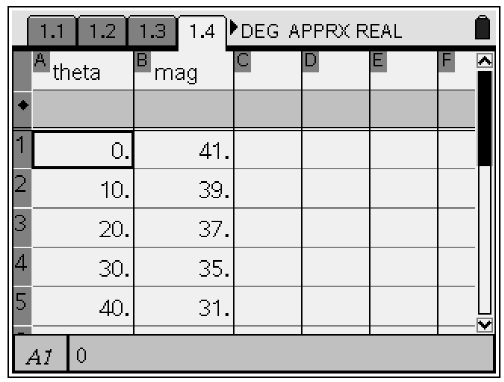
- What is the relationship between magnetic flux and induced emf?

Students will first explore the rotation of a coil in a magnetic field by rotating the coil manually. Then, they will explore animations that show the rotations in real time.

Problem 1 – Manual generation of magnetic flux and emf curves

Step 1: Students should open the file **PhysWeek31_Electromagnetism.tns** and read the first two pages. Page 1.3 shows a coil (thick, solid line) that can rotate in a magnetic field (vectors). The angle of the coil is shown at the top of the page. Students should rotate the coil 360º in 10º increments. At each position, they should count the number of field lines (both solid and dotted) that pass through (intersect) the coil. They should record their counts in the *Lists & Spreadsheet* application on page 1.4. Between the angles of 90º and 270º, students should record the negative of the number of field lines that pass through the coil. If they do not understand why they should do this, remind them that the number of field lines at each position is a proxy for the magnetic flux through the coil at that position and that the sign on magnetic flux depends on the "direction" in which the magnetic field lines cross the coil. Between 90º and 270º, the magnetic field lines intersect the coil in the opposite direction from that when the coil is between 270º and 90º. Note: Students may have difficulty visualizing the solid line as a coil. Explain that the coil is simply a loop of wire, and when it is shown from the side (as it is here), it appears as a straight line.

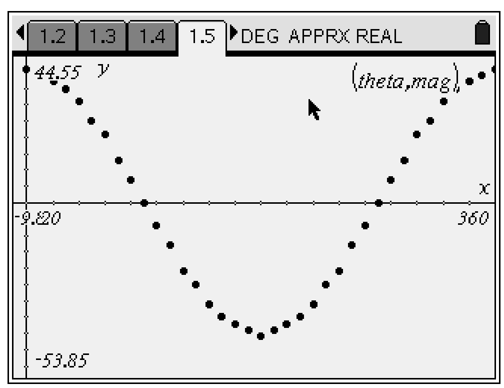




Step 2: Page 1.5 is a graph of **mag** vs. **theta** for the data the students collected in step 1. Students should examine the plot and then answer questions 1–4.

Q1. What shape does the graph of **mag** vs. **theta** have?

A. *The curve should approximate a cosine curve.*



Q2. At what points is the induced emf in the coil zero?

A. *Induced emf is zero at the points with the least change in magnetic flux (number of field lines) per interval of angular change. These points occur at the crests and troughs of the sine curve—that is, at 0º, 180º, and 360º.*

Q3. At what points is the magnitude of the induced emf in the coil maximum?

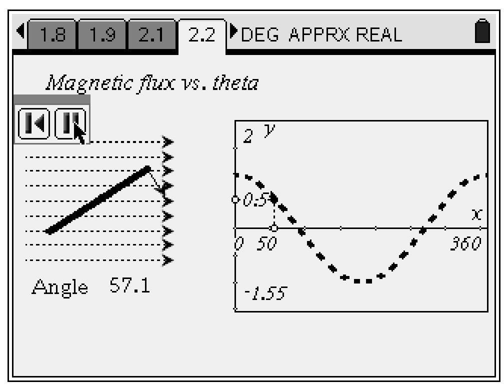
A. *Induced emf is maximum at the points with the greatest change in magnetic flux (number of field lines) per interval of angular change. These points occur where the curve intersects the* x-*axis—that is, at 90º and 270º.*

Q4. Sketch a graph of the change in magnetic flux vs. angle for the data you collected. (Hint: The change in magnetic flux is the slope of the curve on page 1.5.)

A. *Students should be able to estimate the slope of the curve at the various points. They should sketch a sine curve (i.e., a cosine curve phase shifted by 90º) to represent change in magnetic flux vs. angle.*

Problem 2 – Animation of magnetic flux vs. angle

Step 1: Next, students should read page 2.1 and then move to page 2.2. Page 2.2 shows an animation of a rotating coil, together with a graph of magnetic flux vs. angle. Students should study the animation and then answer questions 5 and 6.



Q5. Does the animation agree with the data you collected in problem 1? Describe any differences you observe.

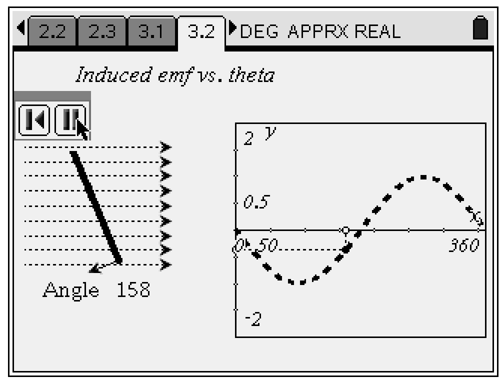
A. *The curves should be very similar. The curve that is based on the animation will probably be smoother and "cleaner" than the graph students created.*

Q6. Explain why the *x*-axis of the graph could be changed to show time and re-scaled without significantly changing the shape of the graph.

A. *The coil rotates at a constant rate. Therefore, the angular change is a function of time.*

Problem 3 – Animation of induced emf vs. angle

Step 1: Next, students should read page 3.1 and then move to page 3.2. Page 3.2 shows an animation of a rotating coil, together with a graph of induced emf vs. angle. Students should study the animation and then answer question 7.



Q7. Does the graph of induced emf in the animation match the sketch you made for question 4? If not, explain any differences.

A. *If students correctly sketched the graph in question 4, the graphs should look similar. If students made incorrect sketches in question 4, encourage them to discuss any errors in their reasoning.*

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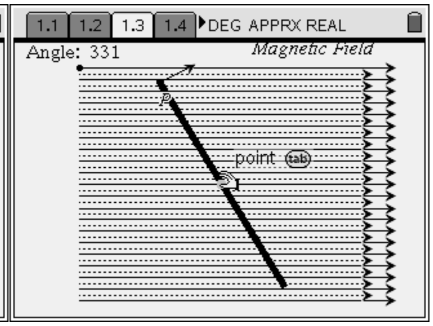
(Student)TI-Nspire File: *PhysWeek31_Electromagnetism.tns*

ELECTROMAGNETISM

Physics

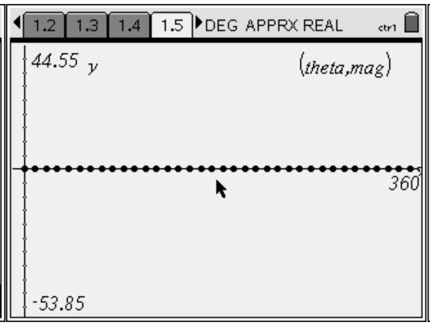
Generating Electricity

The next page shows a coil (thick, solid line) that is moving through a magnetic field (solid and dotted arrows). Rotate the coil through different angles and count the number of magnetic field lines that pass through the coil at each angle. This is proportional to the magnetic flux through the coil.



A theta	B mag	C	D	E	F
0.	0.				
10.	0.				
20.	0.				
30.	0.				
40.	0.				

A1 0



1. What shape does the graph of **mag** vs. **theta** have?

The enduced emf in a coil over a given time interval is calculated using the equation below:

$$emf \propto \frac{\text{change in magnetic flux}}{\text{change in time}}$$

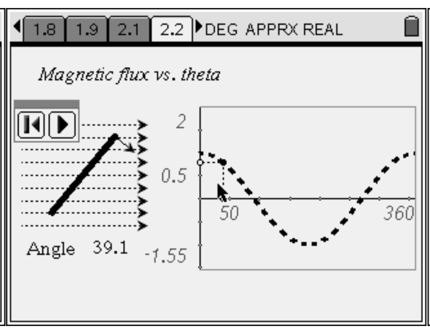
The number of field lines passing through the coil is proportional to the magnetic flux.

2. At what points is the induced emf in the coil zero?

3. At what points is the magnitude of the induced emf in the coil maximum?

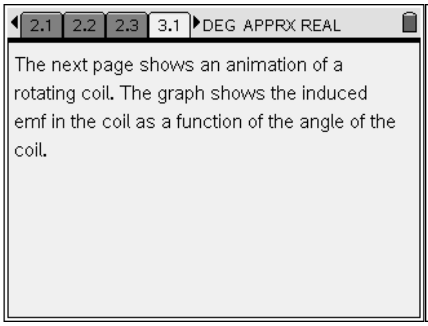
4. Sketch a graph of the change in magnetic flux vs. angle for the data you collected. (Hint: The change in magnetic flux is the slope of the curve on page 1.5.)

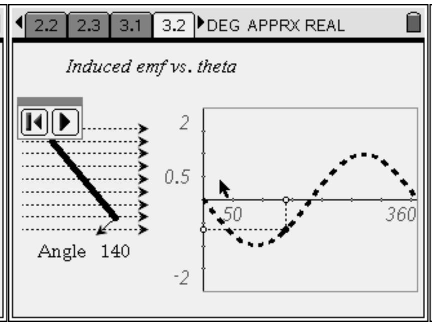
The next page shows an animation of a rotating coil. The graph shows the magnetic flux through the coil as a function of the angle of the coil.

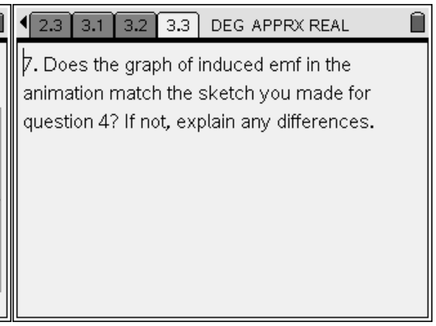


5. Does the animation agree with the data you collected in problem 1? Describe any differences you observe.

6. Explain why the x-axis of the graph could be changed to show time and re-scaled without significantly changing the shape of the graph.


2.1 2.2 2.3 3.1 DEG APPRX REAL
The next page shows an animation of a rotating coil. The graph shows the induced emf in the coil as a function of the angle of the coil.


2.2 2.3 3.1 3.2 DEG APPRX REAL
Induced emf vs. theta
2
0.5
50
360
-2
Angle 140


2.3 3.1 3.2 3.3 DEG APPRX REAL
7. Does the graph of induced emf in the animation match the sketch you made for question 4? If not, explain any differences.