Electromagnetic Induction

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Links to today’s materials

Everything:

[September 2024 Electromagnetic induction]

ALG Chapter 21

[ALG Chapter 21 Final.docx]

OALG Chapter 21

[OALG Chapter 21 Final.docx]

And please rename yourself -

First name High school or colleg Country

Equipment

2 Coils, a galvanometer, bar magnets, an aluminum pipe into which one of your magnets fits easily, wires, power supply to connect one of the coils to, a switch.

Need to know

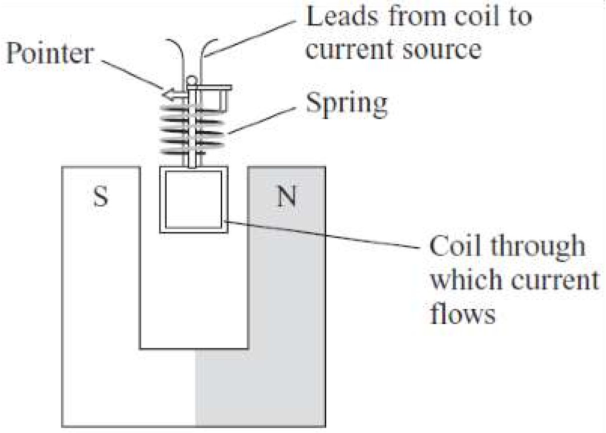
Magnet and a pipe

A galvanometer - how does it work?

20.3.10 Reason

Class: *Equipment per group:* whiteboard and markers.

An old-fashioned galvanometer is a device that serves as a basis for an ammeter and a voltmeter. The galvanometer consists of a coil hanging between the poles of a horseshoe magnet. The coil is supported by a rod that can turn in a ball joint. A spring opposes its turning. A needle, attached to the rod, changes its orientation as the rod turns. The greater the current flowing through the coil, the greater the torque exerted on it by the magnetic field of the magnet, and the more the needle deflects. Discuss how one can make an ammeter and a voltmeter out of the same galvanometer. Imagine that you have resistors of different resistances.



Team 1 OALG 21.1.1 Observe and find a pattern

In the experiments that you will analyze in this activity we use a galvanometer to detect current. You learned how a galvanometer works in Chapter 20, Activity 20.3.10

a. Watch the following video https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-21-1-1 and describe what you observed. What patterns do you notice? Note that the circuit with the galvanometer does not have any battery in it.

b. Develop a rule: Devise a preliminary rule that summarizes **the condition(s) needed to induce a current in a coil**. What are the assumptions that you made?

RULE: Moving the magnet into the coil causes deflection. Into and out cause deflection in opposite directions. Flipping the magnet causes the reverse deflection. Moving the magnet near the coil also. Causes deflection.

Team 2 OALG 21.1.1 Observe and find a pattern

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b. Develop a rule: Devise a preliminary rule that summarizes the condition(s) needed to induce a current in a coil. What are the assumptions that you made?

Relative motion of the magnetic field and the coil produce a movement on the needle. Later the needle returns slowly to its 0 position.

Team 3 OALG 21.1.1 Observe and find a pattern

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a. Watch the following video https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-21-1-1 and describe what you observed. What patterns do you notice? Note that the circuit with the galvanometer does not have any battery in it.

b. Develop a rule: Devise a preliminary rule that summarizes the condition(s) needed to induce a current in a coil. What are the assumptions that you made?

Rule: Relative motion between magnet and the inside of the coil induces a current.

Assumptions: The object as a magnet with different poles. The galvanometer detects current.

Team 1 OALG 21.1.2 Test and revise your idea

The goal of this activity is to test the rule that you invented in Activity 21.1.1. In the following experiments you will have one coil (coil 1) connected to a battery/power supply through the switch. The other coil (coil 2) is connected to the galvanometer.

Experiment 1. Use the rule devised in Activity 21.1.1 part **b**. to predict what will happen if you move coil 1 relative to coil 2.

Prediction: We have an induced current in coil 2 because coil 1 produce a magnetic field (similar to the field produced by the magnet in the earlier activity)

Experiment 2. Use your current rule to predict what will happen when you place a coil connected to a galvanometer next to the coil connected to the battery/power supply (so that axis of the coils coincide). Then you

(1) close the switch without moving either coil,

(2) let the current run for a period of time, and finally

(3) open the switch.

a. Describe the experiments in words and sketches and make the predictions of their outcomes using the rule you invented in Activity 21.1.1.

Experiment 2:

Our prediction (as there are 4 experiments essentially) based on the rule developed earlier: no induced current in the coil 2

Exp 2: 1) There is no relative motion of the coils and there should be no current through galvanometer

2) same as 1

3) same as 1

So the rule/explanation is rejected

Team 2 OALG 21.1.2 Test and revise your idea

The goal of this activity is to test the rule that you invented in Activity 21.1.1. In the following experiments you will have one coil (coil 1) connected to a battery/power supply through the switch. The other coil (coil 2) is connected to the galvanometer.

Experiment 1. Use the rule devised in Activity 21.1.1 part **b**. to predict what will happen if you move coil 1 relative to coil 2.

Prediction of relative motion of coil 1 with current moving relatively to coil 2 will produce a current on coil 2. There is no magnet in these experiments..

Experiment 2. Use your current rule to predict what will happen when you place a coil connected to a galvanometer next to the coil connected to the battery/power supply (so that axis of the coils coincide). Then you

(1) close the switch without moving either coil,

The coil connected to a galvanometer next to a coil with power will show a current when the switch of the power supply of the 2nd coi

But according to our rule about relative motion, we wouldn’t / shouldn’t predict that.

(2) let the current run for a period of time, and finally

(3) open the switch.

a. Describe the experiments in words and sketches and make the predictions of their outcomes using the rule you invented in Activity 21.1.1.

Team 3 OALG 21.1.2 Test and revise your idea

The goal of this activity is to test the rule that you invented in Activity 21.1.1. In the following experiments you will have one coil (coil 1) connected to a battery/power supply through the switch. The other coil (coil 2) is connected to the galvanometer.

Experiment 1. Use the rule devised in Activity 21.1.1 part **b**. to predict what will happen if you move coil 1 relative to coil 2.

Experiment 2. Use your current rule to predict what will happen when you place a coil connected to a galvanometer next to the coil connected to the battery/power supply (so that axis of the coils coincide). Then you

(1) close the switch without moving either coil,

(2) let the current run for a period of time, and finally

(3) open the switch.

a. Describe the experiments in words and sketches and make the predictions of their outcomes using the rule you invented in Activity 21.1.1.

EXP1 Prediction according to our rule: Induced current.

EXP 2 Prediction according to our rule: No induced current.

All together

b. Watch both experiments here [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-21-1-2] and compare the outcomes to the predictions.

c. Make a judgment concerning the rule that you're testing. If necessary, revise your rule to incorporate your new findings. Note that your revised rule should be consistent with *all* the experiments you've conducted up to this point.

Time for telling

We can create an induced current with a changing magnetic field (relative motion or turning on/off a magnetic field)

Team 1 ALG 21.2.2 and 21.2.3 ALG Chapter 21 Final.docx

22.2.2

Work with your group members to devise a mathematical expression that relates the *magnitude* of the induced current to various properties of the magnetic field, relative motion of the coil with respect to the magnet, and properties of the coil.

RULE: the induced current depends on: 1) strength of magnet 2) area of coil 3)speed with which the coil moves 4) the orientation of the coil in respect to the magnetic field of the magnet is also important. It is maximum where they are perpendicular.

22.2.3

Imagine that rain is falling at a rate of 100 drops per second, per square meter (100 drops/s/m2).

a. In each of the following three scenarios, work with your group members on a whiteboard to

estimate how much rain (in units of drops) you will collect in 1 minute in the box. You should

assume the rain falls vertically.

a. **Area of whiteboard: 2 m^2 so in 1 minute we have: 100 drops X 60 X2=12000 drops**
b. **Area of whiteboard: 6 m^2 therefore: 36000 drops**
c. **30° tilted above the horizontal: effective area is: 2 m^2 cos30°= 2X0.87m^2. 100 drops X60 X 1.73m^2=10392drops**

POINT b:

Team 2 ALG 21.2.2 and 21.2.3 ALG Chapter 21 Final.docx

$I \propto v$

$I \propto B$

$I \propto$ angle (at 90 degrees is highest and at 0 degrees is lowest)

$I \propto$ Area of coil

5: $I \propto v*B*A*\cos\Theta$

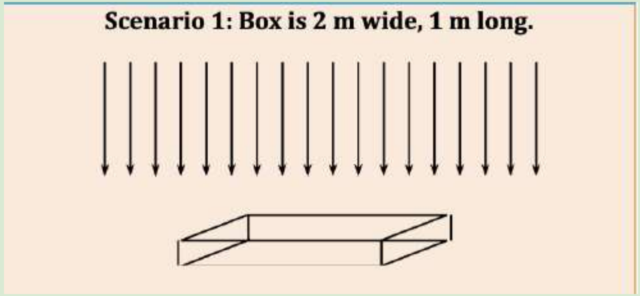
[A] $\propto$[m/s]*

$\cos\Theta$ (angle measured from a coil perpendicular to B)

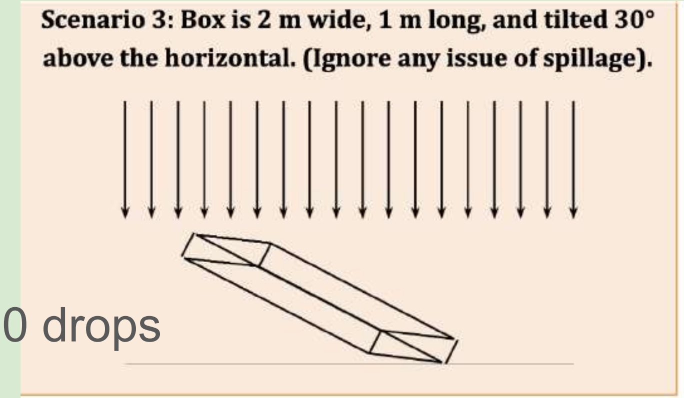
Team 3 ALG 21.2.2 and 21.2.3 ALG Chapter 21 Final.docx

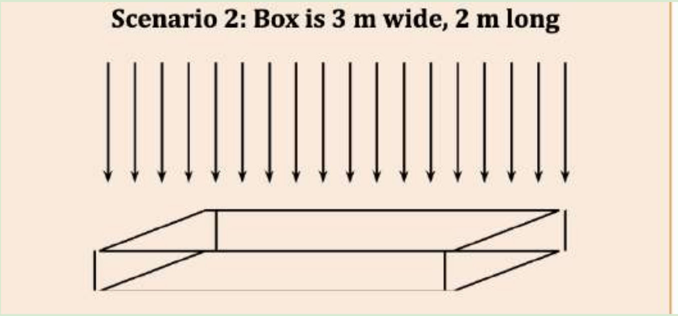
l B (magnetic field), cos (θ), Area, Δrelative position/Δtime

l depend on B*A*(Δx/Δt)*cos (θ)



12000 drops





36000 drops

10400 drops

Time for telling

Magnetic flux BAcos (θ)

Changing flux causes electric current through a coil

If you have equipment

21.2.1 Observe and find a pattern

***PIVOTAL* Lab:** *Equipment per group:* whiteboard, markers, coils with different diameters and different numbers of turns, 2-3 bar magnets, a galvanometer (or a multimeter).

By now, your group has figured out how to use a magnet to induce a current in the coil. Your goal for this experiment is to devise a qualitative rule that relates the *magnitude* of induced current to the properties of the magnet, the motion of the magnet, and the properties and the orientation of the coil.

a. Come up with as complete a list as possible of possible factors that might affect the magnitude of the current induced in the coil. Then conduct the experiments to instigate those factors.

b. Briefly describe your experiments using sketches and words.

c. Describe the outcomes of your experiments.

d. Use your experiments and any other information you have to devise qualitative rules (in words) that relate the magnitude of induced current to other factors. Are there any assumptions that must be made for your rule to work?

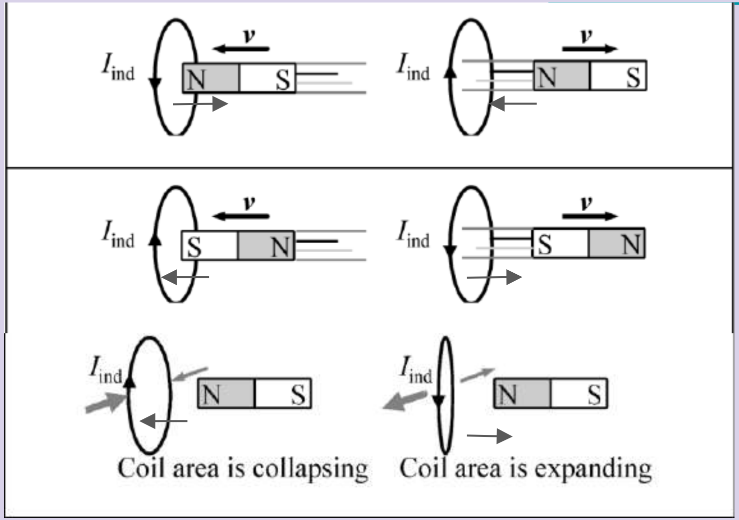
Team 1 ALG 21.2.5

Team 2 ALG 21.2.5

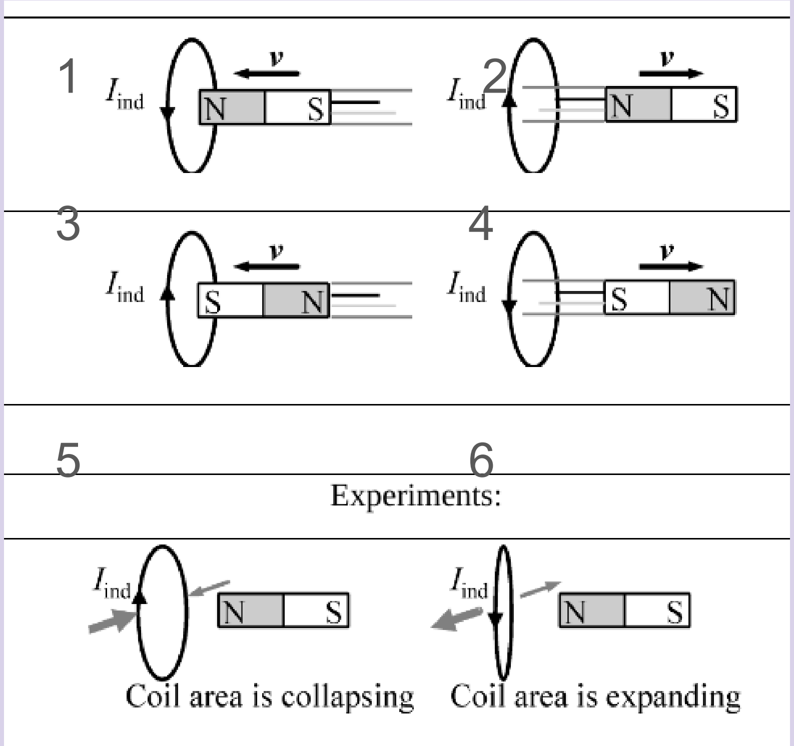
Team 3 ALG 21.2.5

Time for telling

Team 1 OALG 21.3.1 OALG Chapter 21 Final.docx



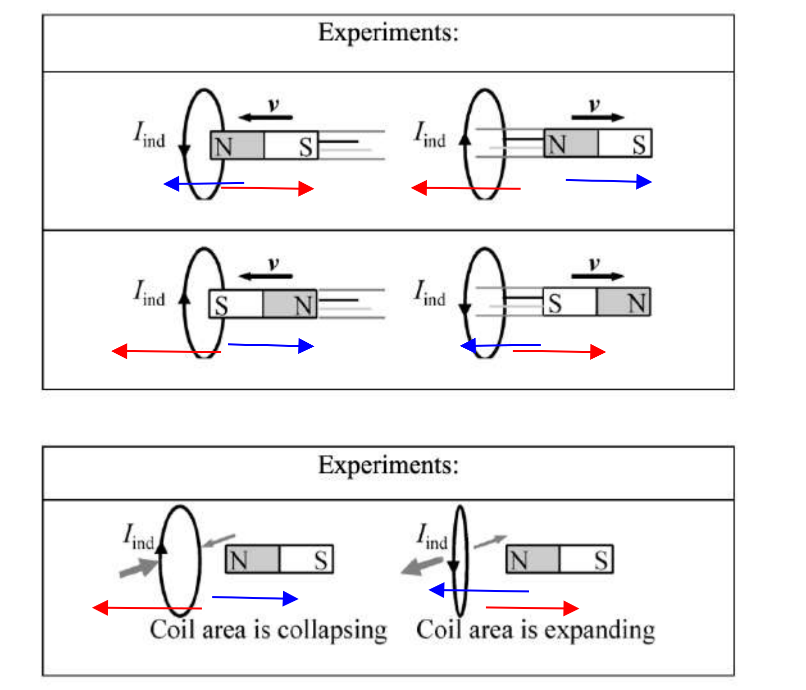
Team 2 OALG 21.3.1 OALG Chapter 21 Final.docx



B_{ext1} and B_{ext6} increasing to left; B_{ind} to right

B_{ext2} and B_{ext5} = decreasing to left, B_{ind} to left

Team 3 OALG 21.3.1 [OALG Chapter 21 Final.docx]



1. Increase in magnetic flux, Magnitude of magnetic field increase
2. Decrease in magnetic flux, Magnitude of magnetic field decrease
3. Increase in magnetic flux in negative direction, Magnitude of magnetic field increase
4. Decrease in magnetic flux in positive direction, Magnitude of magnetic field decrease
5. Decrease in magnetic flux to the right
6. Increase in magnetic flux to the left

The induced current induces magnetic field is opposite the direction of the change in magnetic flux.

Time for telling

Team 1 OALG 21.3.3 OALG Chapter 21 Final.docx

Team 2 OALG 21.3.3 OALG Chapter 21 Final.docx

Team 3 OALG 21.3.3 OALG Chapter 21 Final.docx

Team 4 OALG 21.3.3 OALG Chapter 21 Final.docx

All together ALG 21.3.3 ALG Chapter 21 Final.docx

All together ALG 21.3.4 ALG Chapter 21 Final.docx

Team 1 ALG 21.4.1ALG Chapter 21 Final.docx

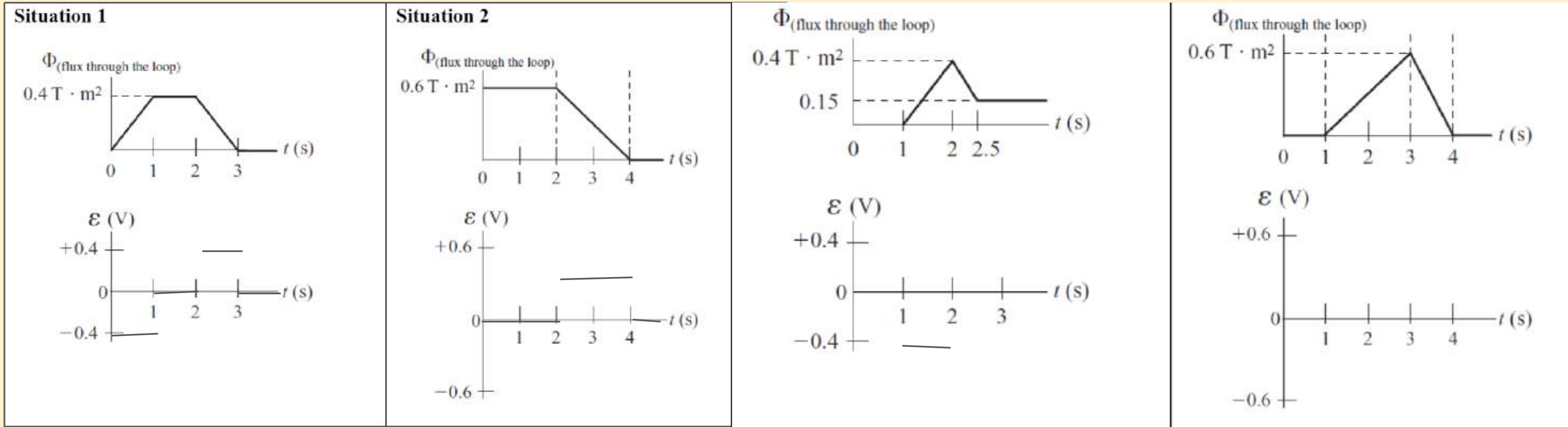
Team 2 ALG 21.4.1 ALG Chapter 21 Final.docx

Team 3 ALG 21.4.1 ALG Chapter 21 Final.docx

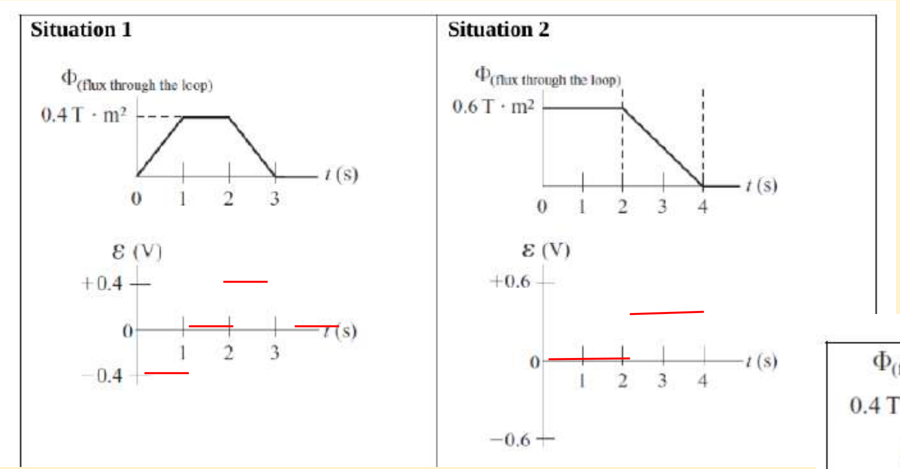
Team 4 ALG 21.4.1 ALG Chapter 21 Final.docx

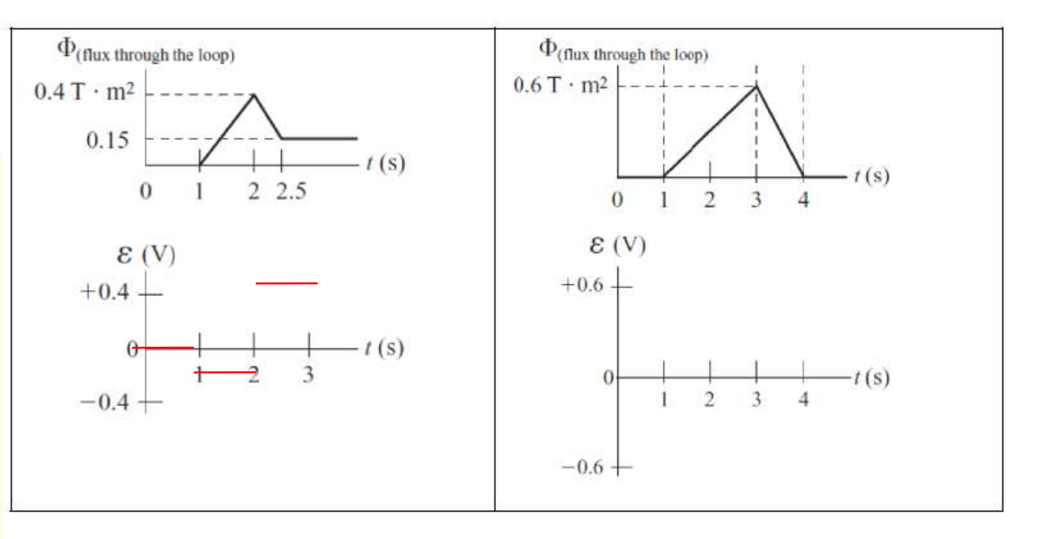
Team 1 ALG 21.4.2, 21.4.3 [ALG Chapter 21 Final.docx]

What did you find in 21.4.2?

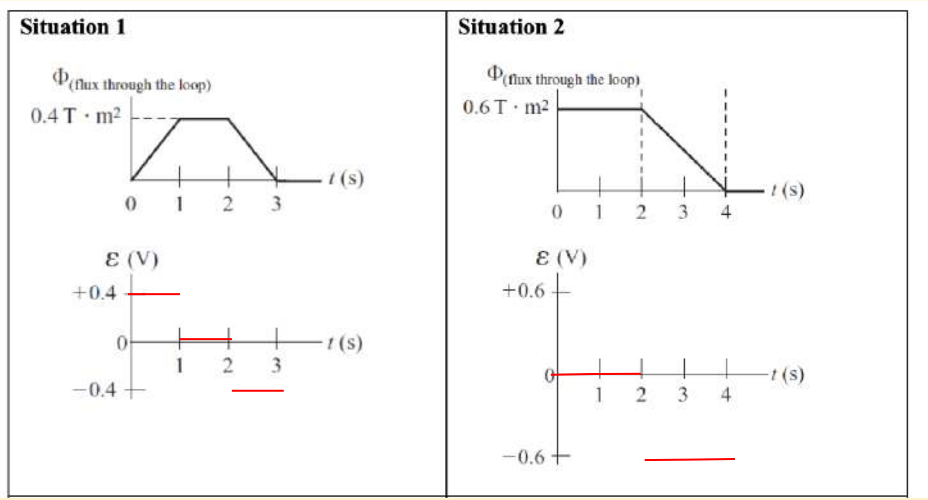


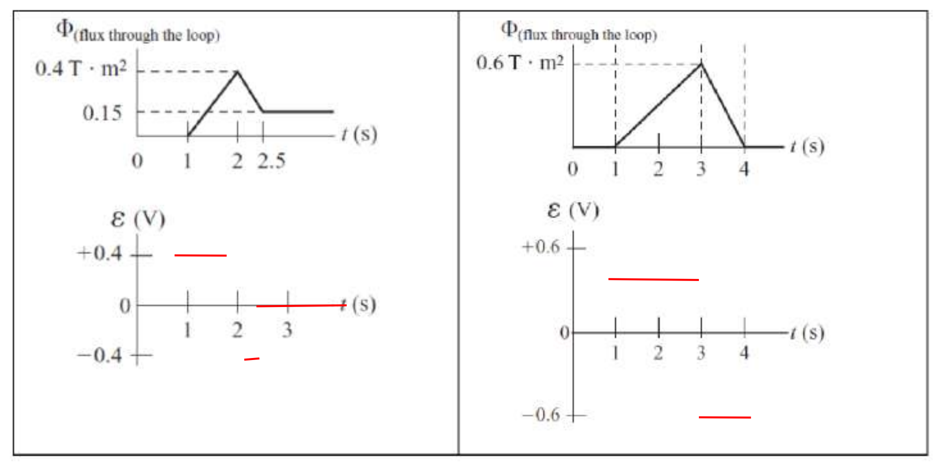
Team 2 ALG 21.4.2, 21.4.3 [ALG Chapter 21 Final.docx]





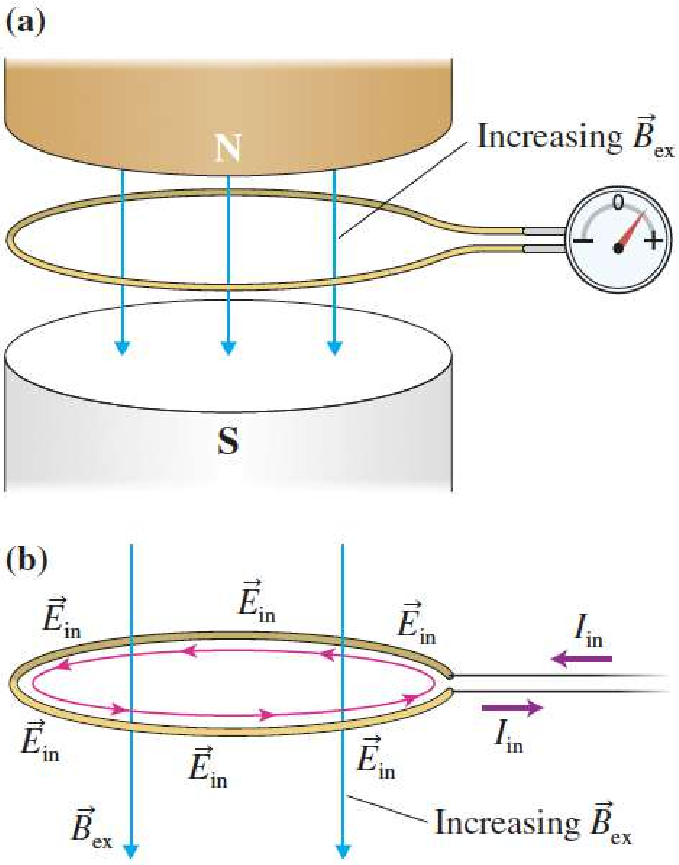
Team 3 ALG 21.4.2, 21.4.3 ALG Chapter 21 Final.docx





How does changing magnetic field create an induced current?

FIGURE 21.26 A changing $\vec{B}_{ex}$ creates an electric field $\vec{E}$ that induces an electric current.



What did you learn today and how did you learn it?

Changing flux creates new electric field that exists even if the is no coils

Interesting way to develop the idea of Lenz Law. I never considered the idea that the induced magnetic field would would repel a magnet. This would be good to mention to the students.

A good way to visualize Lenz’s law

Interesting that students will perhaps think better about repelling magnetic poles,

Instead of of opposite B field vectors

I learned that we can model/think of a coil with current flowing through it as a magnet as another way to think about the direction of the induced magnetic field

I learn about the steps to show for electromagnetic induction: by finding the possible measurements that influence magnetic flux. The ability to show it experimentally.

If time permits ALG 21.5.4 ALG Chapter 21 Final.docx