Large Room Meeting I (Chapter 21.1-21.2)

Major Goals

- ◻ Observe the phenomenon of electromagnetic induction and determine the quantities that affect size of the induced current
- ◻ Formulate the quantity of magnetic flux and how to determine it

Need to Know
How does this flashlight work if it doesn't have batteries?

Read and Interrogate Textbook page 649 (make sure that you know how to do everything listed under "Be sure you know how to").

21.1.1 – Observational Experiment
Observe these video experiments involving a bar magnet and a coil of wire connected to a galvanometer (an analog device for detecting current). Record your observations in the handout.

What patterns did you notice?

Clicker Question #1

Read and Interrogate Textbook page 650.

21.1.2 – Testing Experiment
Use the rule we just devised to predict the outcome of the experiments conducted with the setup on the slides

Experiment	Prediction	Outcome
Switch is open for Coil 1 (no current through it)		
When the switch is closed for Coil 1 (current increases)		
Switch is closed for Coil 1 (constant current)		
When switch is opened for Coil 1 (Current decreases)		

Once you have made your predictions, watch this video of these experiments and record the outcomes.
Did our rule lead to accurate predictions?

Time for telling

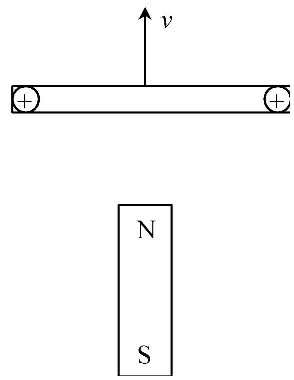
Read and Interrogate Textbook Pages 651-654.

Clicker Question #1

Read and Interrogate
For more information, read through and interrogate pages 650 – 654.

21.1.5 – Explain
Now we want to develop a microscopic explanation for this rule.

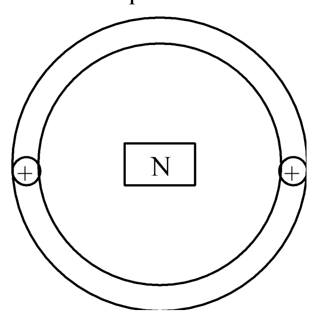
Side View



A loop of wire is moving up away from the magnet at a speed v. Draw the magnetic field created by the magnet passing through the loop at the instant shown.

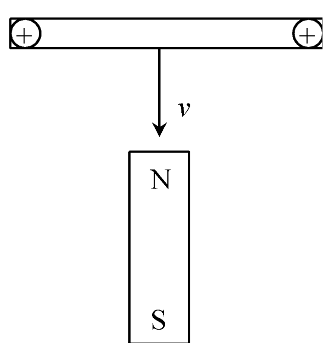
The same loop is moving up, away from the magnet but viewed from above. Draw the force exerted on each of the charges shown in the loop.

Top View

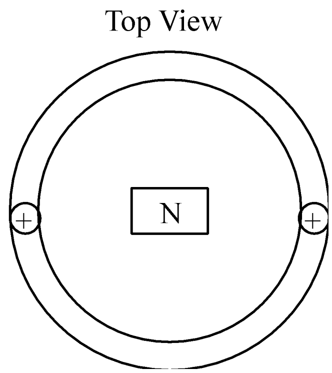


A loop of wire is moving down towards the magnet at a speed v. Draw the magnetic field created by the magnet passing through the loop at the instant shown.

Side View



The same loop is moving down, toward the magnet but viewed from above. Draw the force exerted on each of the charges shown in the loop.



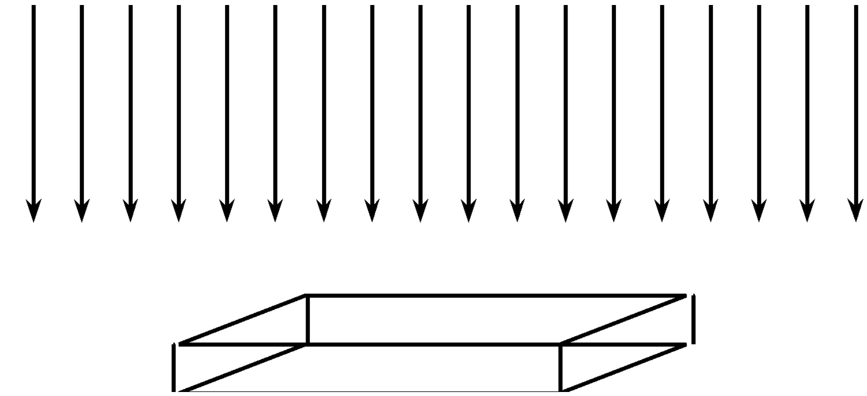
Summary of What we Know so Far

<u>For help Review Section 21.1 in the textbook.</u>

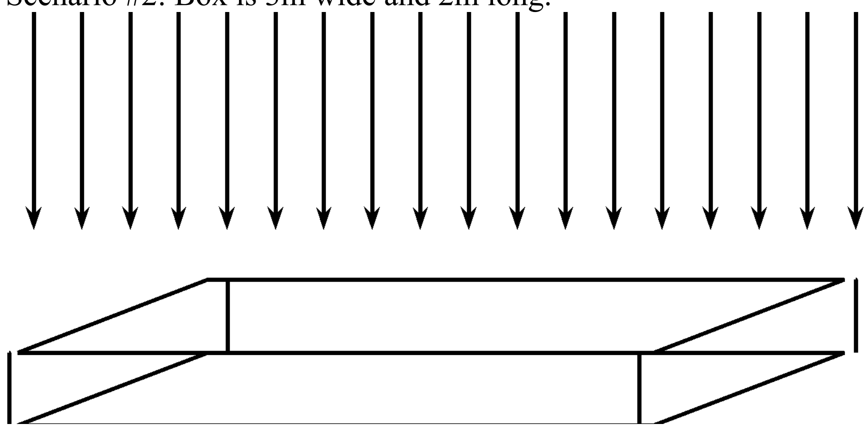
21.2.3 – Reason

Imagine that rain is falling vertically at a rate of 100 drops per second, per square meter ($100\frac{drops}{s \cdot m^2}$). Estimate how many raindrops you will collect in each of the following boxes.

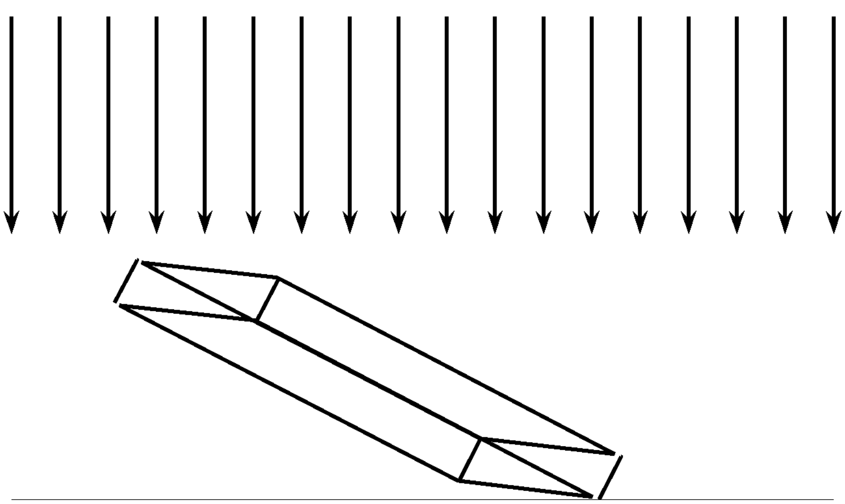
Scenario #1: Box is 2m wide and 1m long.



Scenario #2: Box is 3m wide and 2m long.



Scenario #3: Box is 2m wide, 1m long, and tilted at 30^o

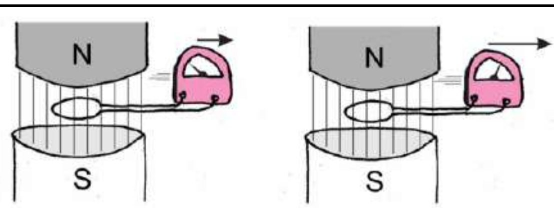


Clicker Question #2

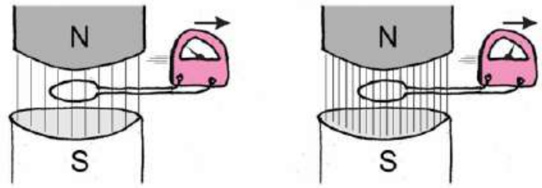
Clicker Question #3

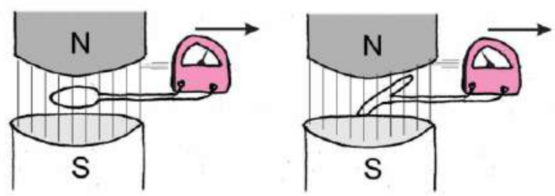
21.2.2 – Observational Experiment

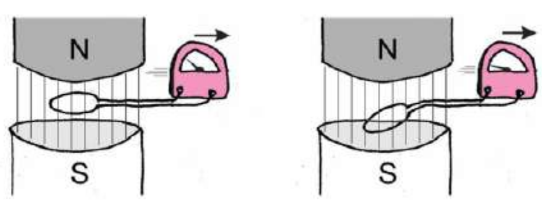
The table below lists the outcomes of various experiments. Identify patterns and use these results to derive an expression which describes how various properties of the magnetic field and the coil affect the magnitude of the induced current.

Experiment	**Illustration**	**Outcome**
Position a coil so that the $\vec{B}$-field lines are perpendicular to it and move it slowly out of the magnetic field. Repeat the experiment, moving the coil quickly.		The quicker the coil's motion, the larger the induced current.

Experiment	**Illustration**	**Outcome**

Position the magnet and the coil as in the experiment. and move the coil slowly out of the magnetic field. Repeat the experiment using a stronger magnet.		A stronger magnet induces a stronger current in the coil compared to a weaker magnet when the coils move at the same speed with respect to the magnet.

Experiment	**Illustration**	**Outcome**
Use two identical coils. Fold part of the wire of one coil to make a loop with a smaller area (see the figure). Position each coil and the magnet as before. Move the coils out of the magnetic field at the same speed with respect to the magnet.		A stronger current is induced in the coil with the larger area.

Experiment	**Illustration**	**Outcome**
Position a magnet perpendicular to the coil and the coil as before. and move the coil slowly out of the magnetic field. Then position the coil so that the plane of the coil makes some other angle with the $\vec{B}$-field		When the $\vec{B}$-field lines are perpendicular to the plane of the moving coil, the strongest current is induced.

lines. Keep the speed the same.		

The proportionalities we've discovered so far are listed below. Combine them into a single expression:

- $I \propto \frac{1}{\Delta t}$, $I \propto \Delta \vec{B}$, $I \propto A$, $I \propto coscos\,\theta$

Time for Telling

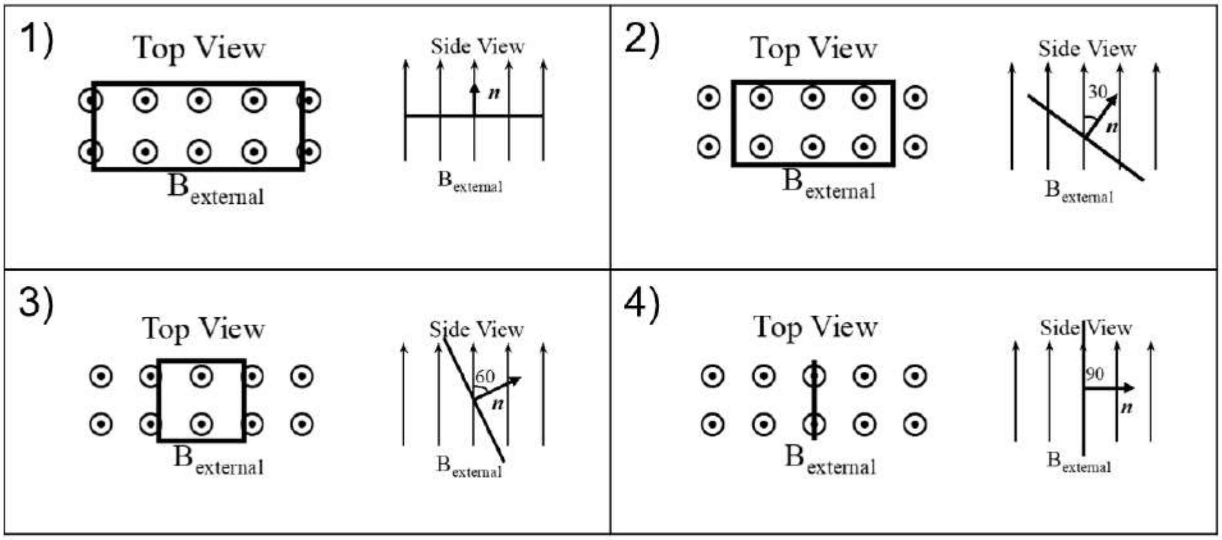
Read and Interrogate

Read and interrogate pages 654 – 655 (Section Magnetic flux).

21.2.4 – Represent and Reason

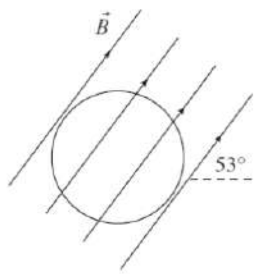
Calculate the Φ for each of the situations shown below. In each case the magnitude $B_{external} =$

$1 \times 10^{-3} T$, the length of the loop is 0.2m and the width of the loop is 0.05m.

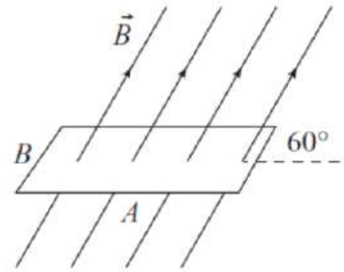


Calculate the Φ for each of the following situations. In all cases the magnitude of B is 0.5T.

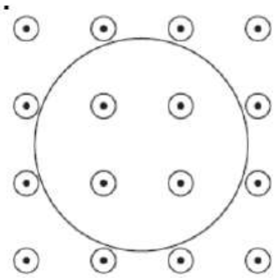
1) Loop and $\vec{B}$ in the plane of the paper. The radius of the circular loop is 5.0 cm.



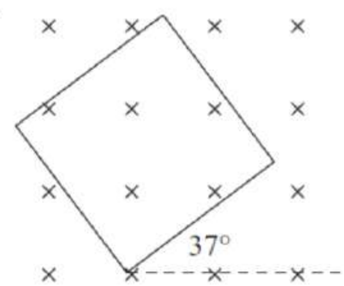
2) Loop perpendicular to the paper and $\vec{B}$ in the plane of the paper. Side A = 0.2 m, side B = 0.1 m.



3) Loop in the plane of the paper $\vec{B}$ out of paper. The radius of the circular loop is 5.0 cm.



4) Loop perpendicular to the paper and $\vec{B}$ in the plane of the paper. Side A = 0.2 m, side B = 0.1 m.



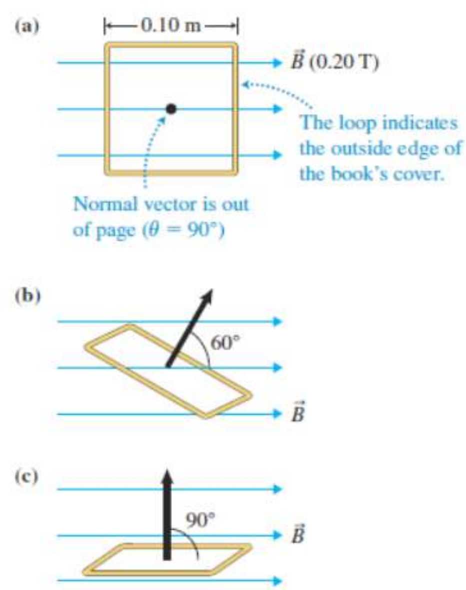
Small Room Meeting (Chapter 20.4 & 21.2)

Major Goals

- ◻ Determine the motion of a charged particle in a magnetic field
- ◻ Practice calculating the flux through a loop of wire in an external magnetic field

Question #1 (Example 20.4) (Clarity, Consistency and Evaluation)

Determine the path of a cosmic ray proton flying into Earth's atmosphere above the equator at a speed of about 10^7 m/s and perpendicular to Earth's magnetic field. The average magnitude of Earth's B-field in this region is approximately 5×10^{-5} T. The mass m of a proton is approximately 10^{-27} kg.



Question #2 (Quantitative Exercise 21.2) (Consistency and Evaluation)

A book is positioned in a uniform 0.20-T B- field that points from left to right parallel to the plane of the page, shown in the figures on the right. (For simplicity, we depict the book as a rectangular loop.) Each side of the book's cover measures 0.10 m. Determine the magnetic flux through the cover when (a) the cover is in the plane of the page (figure a), (b) the cover is perpendicular to the plane of the page and the normal vector makes a 60° angle with the B-field (figure b), and (c) the cover is perpendicular to the plane of the page and the normal vector points toward the top of the page (figure c).

Criterion	Perfect (2)	Needs some work (1)	Needs a lot of work (0)
Clarity	The solution is clear, expressed in words and symbols, takes no effort to comprehend.	The words are lacking but the symbolic part is clear. Takes some effort to comprehend.	Takes a lot of effort to comprehend. There is only math, mostly numbers, not general equations and there are no words explaining the thought process.
Consistency	Two or more different representations are present, they are correct and consistent with each other.	Two or more different representations are present and they are consistent but there are mistakes in representations.	Mistakes in representations or different representations are inconsistent with each other.
Evaluation	The answer is evaluated using at least two of the methods listed below: unit analysis, extreme case analysis, reasonability of the answer, consistency of representations.	The answer is evaluated using only one of the methods listed in "Perfect".	There is no evaluation or there are serious mistakes in the evaluation (wrong units, misunderstanding of how reasonable numbers are).

Large Room Meeting II (Chapter 21.3-21.5)

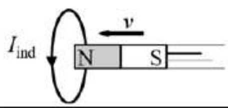
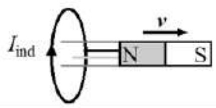
Major Goals

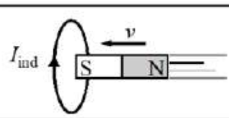
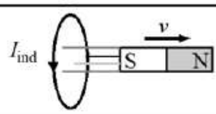
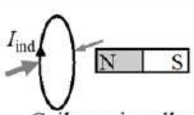
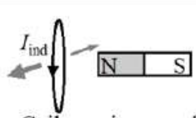
- □ Devise a rule that relates the change in the *external* B-field passing through a coil to the direction of the B-field *induced* by coil.

- ☐ Use Lenz's Law to determine the direction of the current flowing through a loop in various scenarios.
- ☐ Observe the relationship between the average induced emf and the rate of change of magnetic flux (Faraday's Law)

21.3.1 – Observational Experiment

Look at the direction of the current induced around a loop of wire when a magnet is moved nearby.

Experiment	Direction of $\vec{B}_{ext}$	Direction of $\Delta\vec{B}_{ext}$	Direction of $\vec{B}_{ind}$
			
			

Experiment	Direction of $\vec{B}_{ext}$	Direction of $\Delta\vec{B}_{ext}$	Direction of $\vec{B}_{ind}$
			
			
 Coil area is collapsing			
 Coil area is expanding			

Devise a rule that relates the change in the external magnetic field passing through the coil $\Delta\vec{B}_{ext}$

to the direction of the $\vec{B}_{ind}$ induced by the wire.

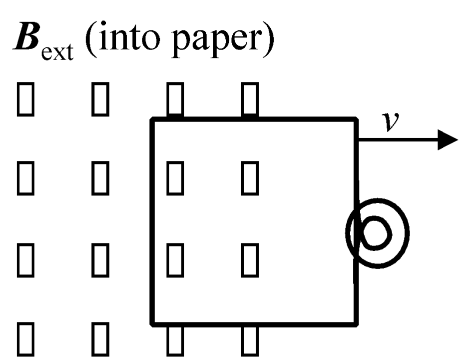
Time for Telling

Read and Interrogate
Read and Interrogate pages 656-658 of the textbook. Work through conceptual exercise 21.3 carefully.

21.3.2 – Guided Practice
Use Lenz's Law to determine the direction of the current flowing through the loop shown below

as it is removed from a region of constant $\vec{B}_{ext}$.

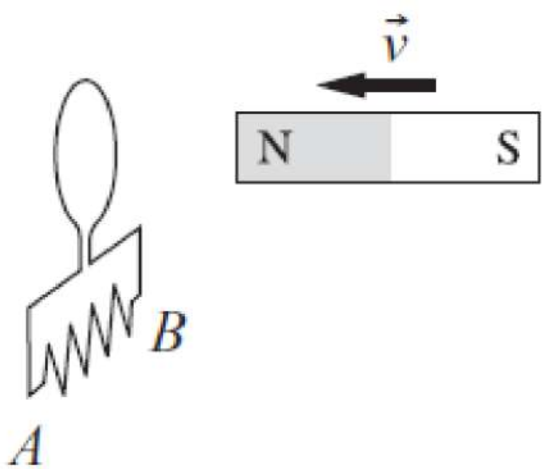
1. Determine the direction of $\vec{B}_{ext}$.
2. Decide whether Φ is increasing, decreasing, or remaining constant.
3. Determine the direction of $\Delta\Phi$.

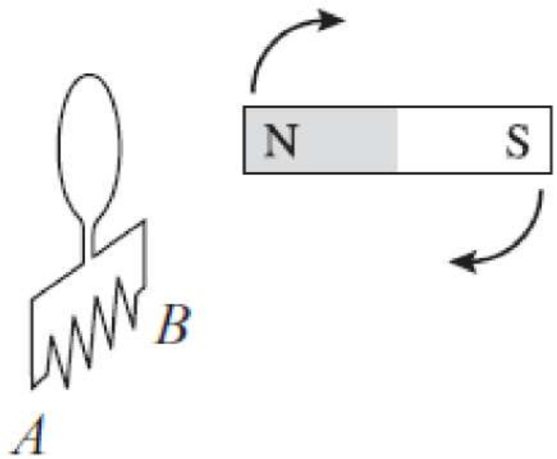


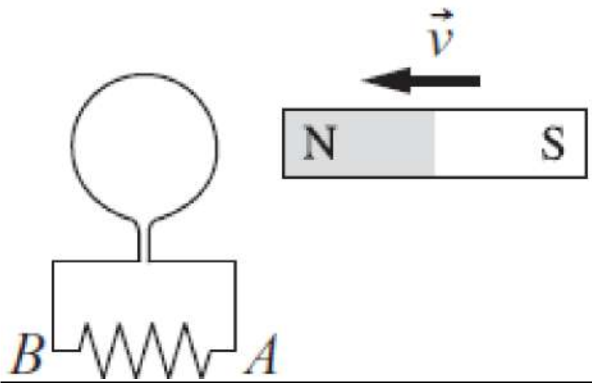
4. Use right-hand rule for magnetic fields to determine the direction of current which would create a $\vec{B}_{ind}$ in the direction opposite to $\Delta\Phi$.

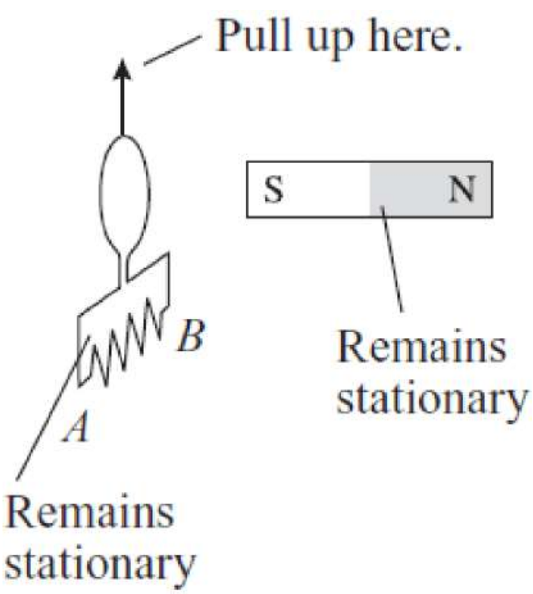
21.3.3 – Reason

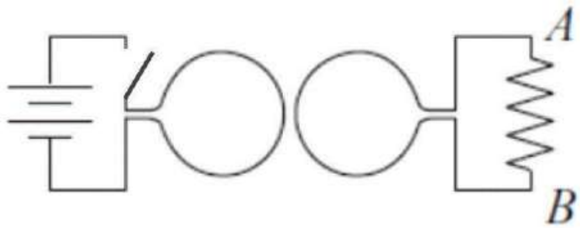
In each of the following cases, predict whether there will be current will be induced through the resistor attached to the loop. If so, say whether the current flows from A to B or from B to A.



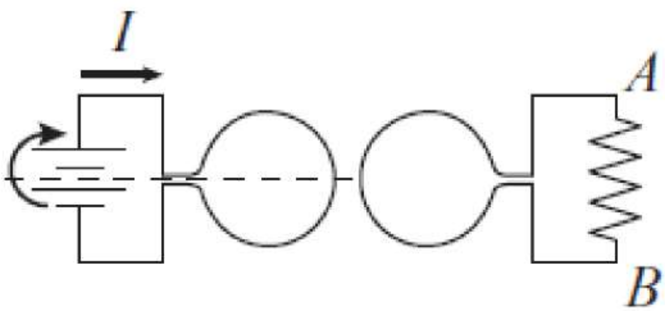

N
S
B
A


$\vec{v}$
N
S
B
A


Pull up here.
S
N
B
A
Remains stationary
Remains stationary



*The switch in the left circuit is closed, and the current increases abruptly.

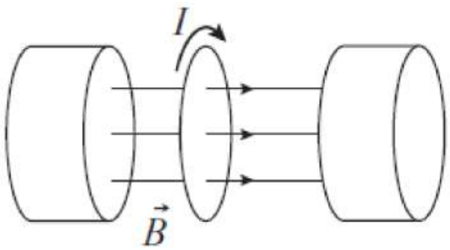


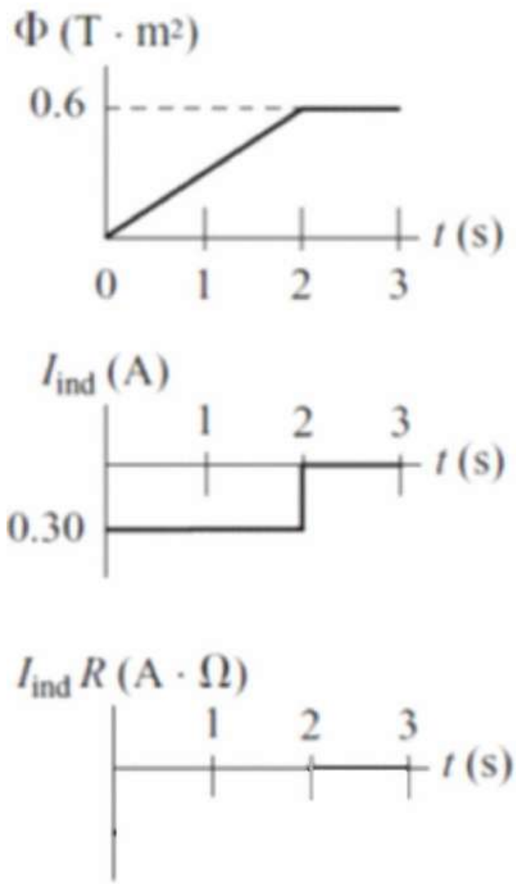
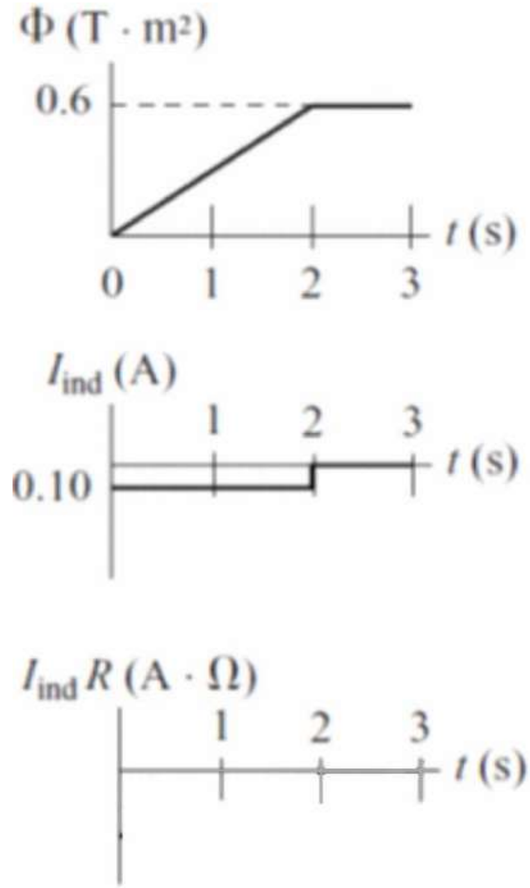
*The circuit on the left is rotated 90^o

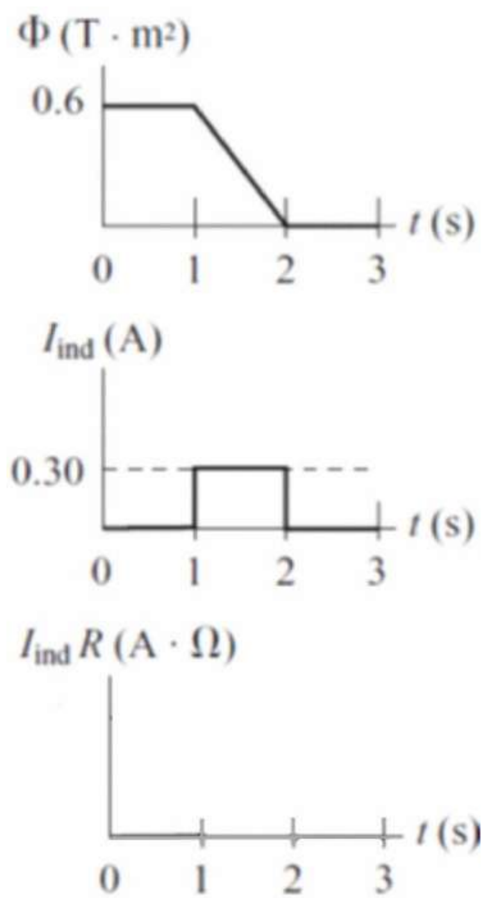
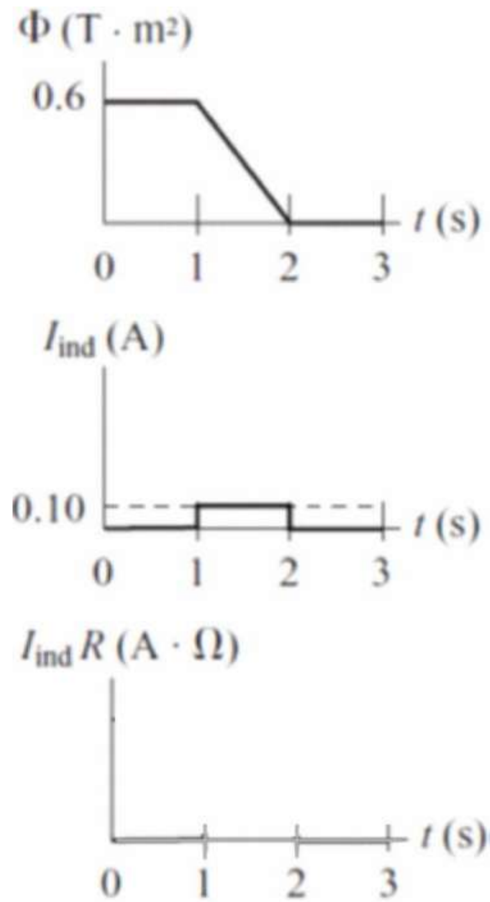
21.4.1 – Reason

Four experiments were done in which loops of wire with different resistances were placed in the changing $\vec{B}$-field produced by an electromagnet (shown below).

For each experiment, graphs of $\Delta\Phi$ vs. t and I_{ind} vs. t are shown. Draw a graph of the product $I_{ind} \cdot R$ vs. t.



<table>
<tr><td>Coil Resistance is 1.0Ω</td><td>Coil Resistance is 3.0Ω</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

<table>
<tr><th>Coil Resistance is 2.0Ω</th><th>Coil Resistance is 6.0Ω</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

21.4.1 – Observational Experiment
Think back to what we learned about circuits. What quantity could the product $I_{ind}R$ represent?

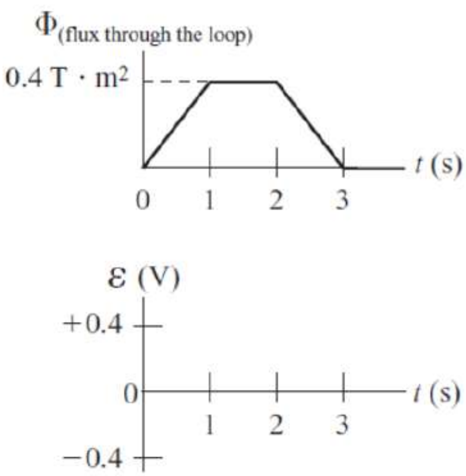
Devise an expression to relate that quantity to $\frac{\Delta\Phi}{\Delta t}$. Do not forget the signs!

Time for Telling

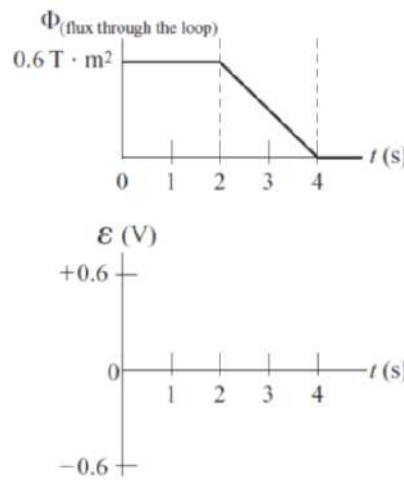
Read and Interrogate Section 21.4 (all of it, especially work through Quantitative Exercise 21.4).

21.4.2 – Represent and Reason
Four situations are shown in which the external flux through a loop is plotted as a function of time. In the table that follows, draw another graph that shows the induced emf in the loop as a function of time.

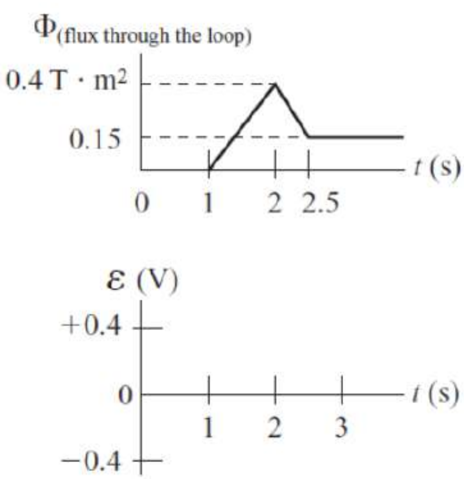
Situation 1



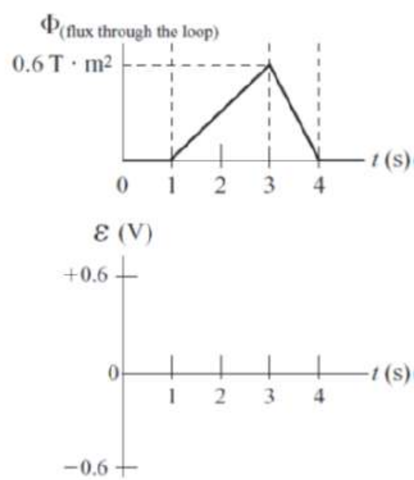
Situation 2



Situation 3

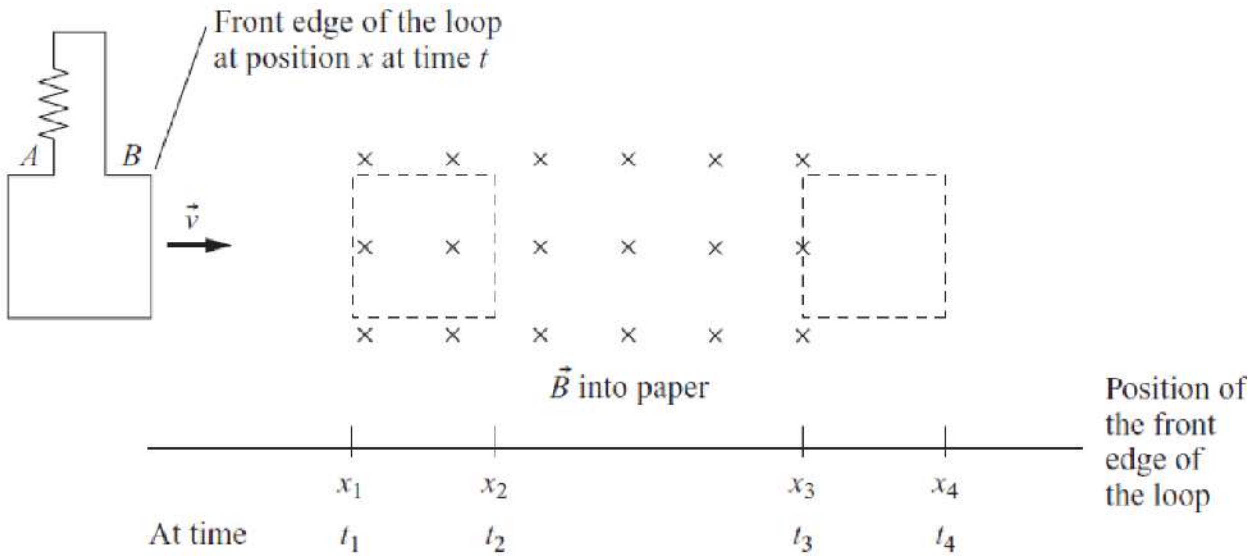


Situation 4



21.4.3 – Represent and Reason
A rectangular loop with a resistor is pulled at constant velocity through a uniform external magnetic field that points into the paper in the regions shown in the illustration with the crosses (

×).



Plot a qualitative graph of the magnetic flux through the loop vs. time.

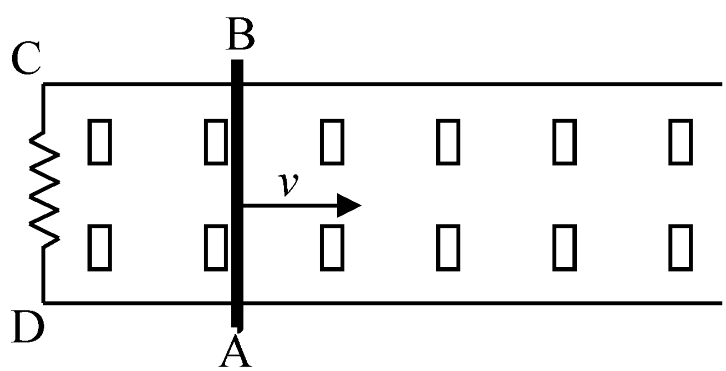
Plot a qualitative graph of the current through the loop vs. time.

21.5.2 – Practice

A horizontal bar is pulled at constant velocity of 2 m/s through a 0.5 T downward-pointing magnetic field. The bar slides on two horizontal, frictionless metal rails moving away from a resistor connected between the ends of the rails. (The distance between the rails is 0.50 m.) Find

the induced current through the resistor of resistance $R = 10\Omega$ in terms of any or all quantities

given.



Plot a graph of flux through the area surrounded by rails, the moving bar and the resistor at the end of rails as a function of time.

Draw a consistent emf-versus-clock-reading graph.

Represent the flux, change in flux, and emf mathematically.

Combine the mathematical representation with Ohm's law to determine the current through the resistor.

Read and Interrogate Work through Examples 21.5- 21.7 in Section 21.5