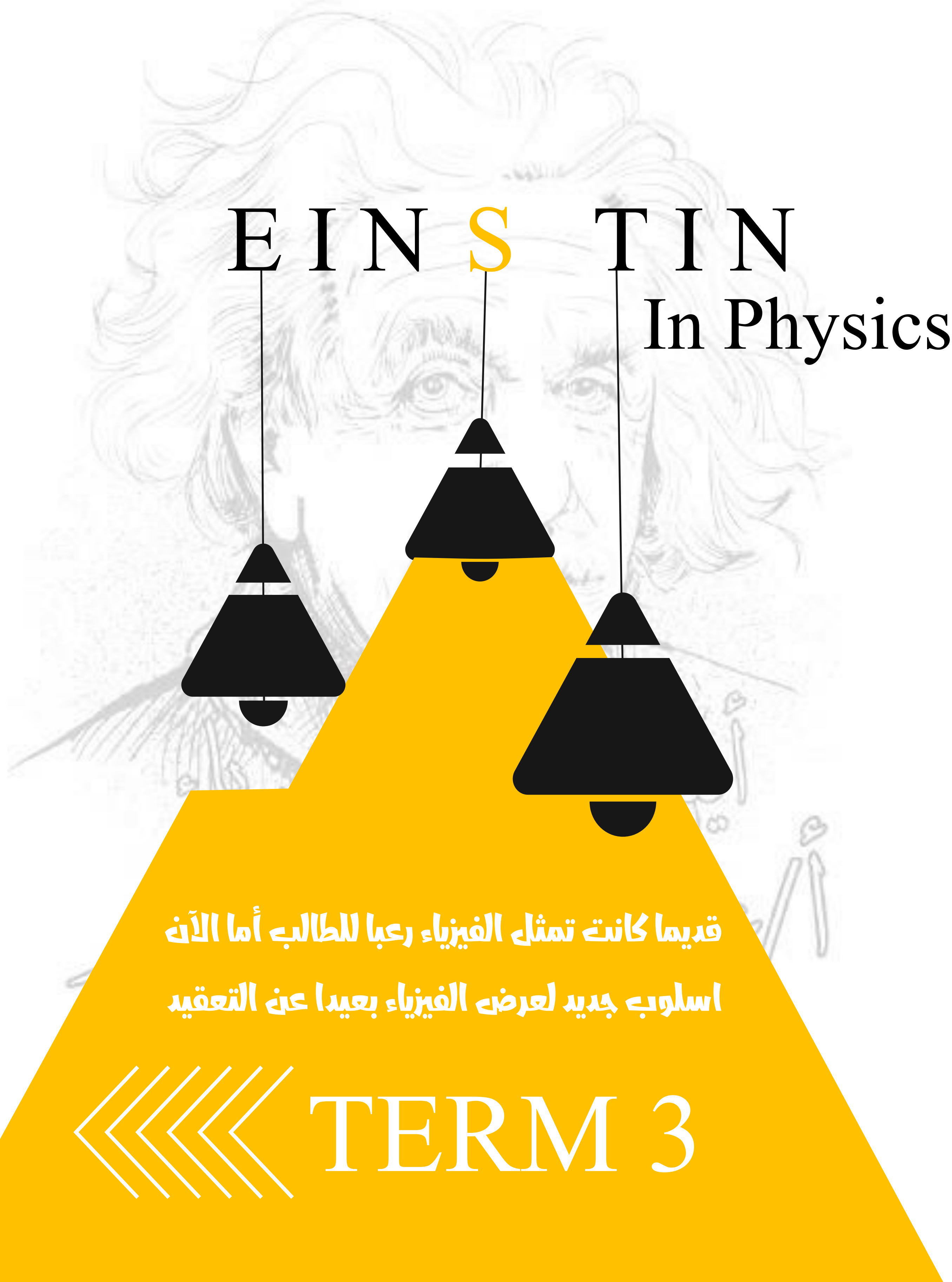
ملزمة الوحدة التاسعة Induction Electromagnetic

إعداد: عبد الرحمن عصام

اسم الطالب: ....



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In Physics

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اسلوب جديد لعرض الفيزياء بعيدا عن التعقيد

TERM 3

Electromagnetic Induction

1- Faraday's experiments

2- Faraday's law of induction

3- lenz's law

4- Generators and Motors

5-induced electric Field

6-inductance of a Solenoid

7-Self-inductance and Mutual induction

8-RL CIRCUIT

9-Energy and energy Density of a Magnetic Field

Chapter 9
Electromagnetic Induction

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2024

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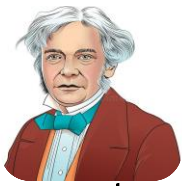
1 Faraday's experiments

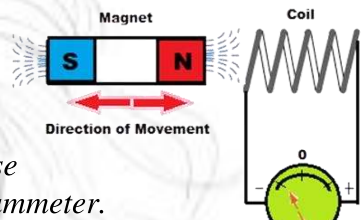


Faraday

- ❖ *a changing magnetic field could generate a potential difference in a conductor, strong enough to produce an electric current.*
- ❖ *This discovery is of basic importance to all the electrical and magnetic devices we use every day, from computers to cell phones, from television to credit cards, from the tiniest batteries to the largest electrical power grid.*

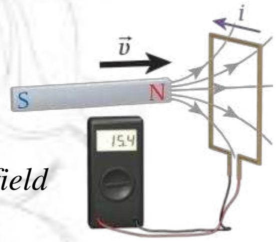
How to understand Faraday's experiments?

1. *consider a wire loop connected to an ammeter.*
2. *A bar magnet is some distance from the loop with its north pole pointing toward the loop.*
3. *While the magnet is stationary, no current flows in the loop.*
4. *However, if the magnet is moved toward the loop, a counterclockwise current flows in the loop as indicated by the positive current in the ammeter.*



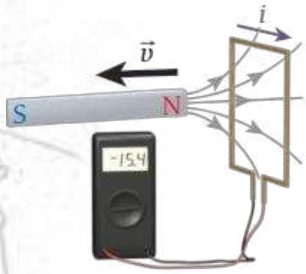
Important notes:

1. *The magnet (North Pole) is moved toward the loop*



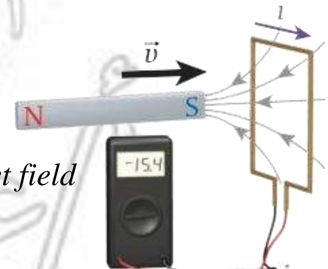
A. *Generate positive induced current (Counterclockwise)*
B. *The magnetic field created in the loop due to the induced current*
C. *The direction of the field in the loop is opposite to the direction of the magnet field*
D. *The magnetic pole created by the loop (the north pole)*

2. *The magnet (North Pole) is moved reversed (back word) the loop*



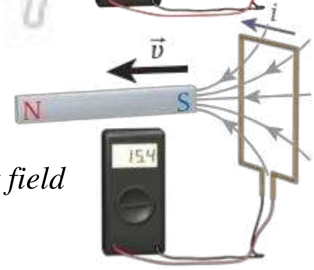
A. *Generate negative induced current (clockwise)*
B. *The magnetic field created in the loop due to the induced current*
C. *The direction of the field in the loop is the same direction of the magnet field*
D. *The magnetic pole created by the loop (the south pole)*

3. *The magnet (South Pole) is moved toward the loop*



A. *Generate negative induced current (clockwise)*
B. *The magnetic field created in the loop due to the induced current*
C. *The direction of the field in the loop is opposite to the direction of the magnet field*
D. *The magnetic pole created by the loop (the south pole)*

4. *The magnet (South Pole) is moved back word the loop*

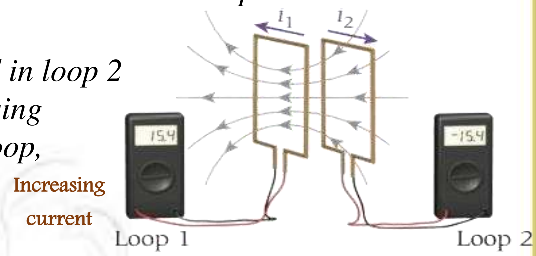


A. *Generate positive induced current (Counterclockwise)*
B. *The magnetic field created in the loop due to the induced current*
C. *The direction of the field in the loop is opposite to the direction of the magnet field*
D. *The magnetic pole created by the loop (the north pole)*

Similar effects can be observed using two conducting loops

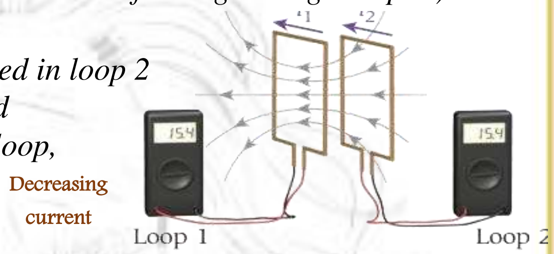
1. *If a constant current is flowing through loop 1, no current is induced in loop 2.*

2. *If the current in loop 1 is increased, a current is induced in loop 2 in the opposite direction. Thus, not only does the increasing current in the first loop induce a current in the second loop, but the induced current is in the opposite direction.*



An increasing current in loop 1 induces a current in the opposite direction in loop 2. (The magnetic field lines shown are those produced by the current 1 flowing through loop 1.)

3. *If the current in loop 1 is decreased , a current is induced in loop 2 in the same direction. Thus, not only does the decreased current in the first loop induce a current in the second loop, but the induced current is in the same direction*

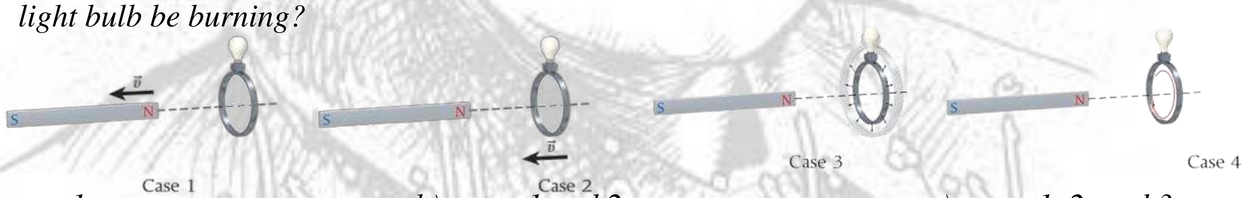


In case (X, .)

- *If the ring or coil inside the magnetic field generates the opposite*
- *If the ring or coil out side the magnetic field generates same*

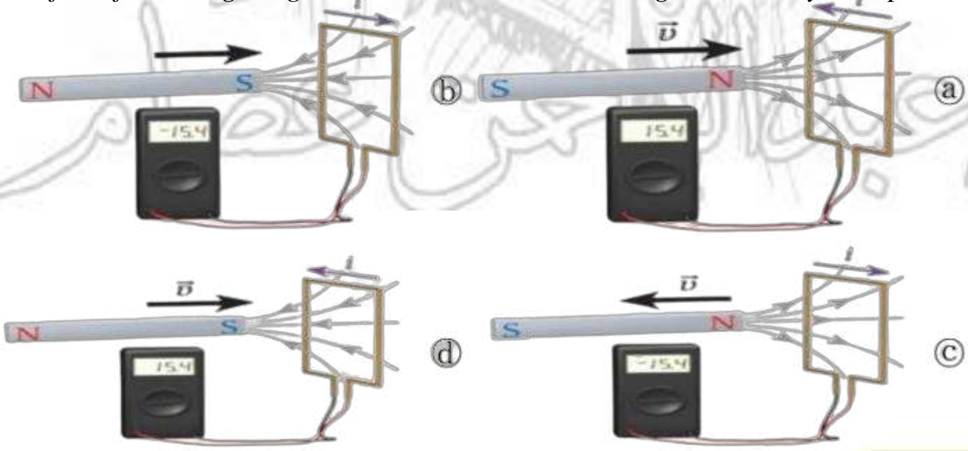
Check your understanding:

1. *The four figures show a bar magnet and a low-voltage light bulb connected to the ends of a conducting loop. The plane of the loop is perpendicular to the dotted line. In case 1, the loop is stationary, and the magnet is moving away from the loop. In case 2, the magnet is stationary , and the loop is moving toward the magnet. In case 3, both the magnet and loop are stationary, but the area of the loop is increasing. In case 4, the magnet is stationary, and the loop is rotating about its center. In which of these situations will the light bulb be burning?*



a) case 1 *b) cases 1 and 2* *c) cases 1, 2, and 3*
d) cases 1, 2, and 4 *e) all four cases*

2. *Which of the following diagram is not correct according to Faraday 's experiments?*



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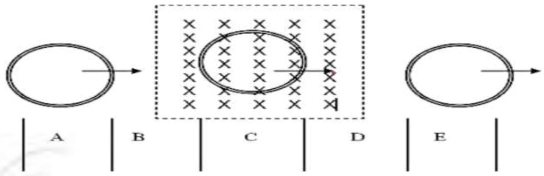
3. A conducting ring is moving from left to right through a region that contains a constant magnetic field as shown in the diagram. In which region is there an induced current in the ring?

ⓐ C ⓒ A and E

ⓑ B, C and D ⓓ B and D



4. ___________ is the generation of current due to relative motion between a wire and a magnetic field.

ⓐ Magnetic flux ⓑ Electromagnetic induction ⓒ Electrolysis ⓓ Electro spectrometry

4. Which of the laws below state that a changing magnetic field through a coil induces a current in it?

ⓐ Ohm's law ⓑ Lenz's law ⓒ Faraday's law ⓓ Kirchhoff's law

5. Faraday's Law of Induction states that___

ⓐ a potential difference is induced in a loop when there is a change in the magnetic flux through the loop

ⓑ the current induced in a loop by a changing magnetic field produces a magnetic field that opposes this change in magnetic field

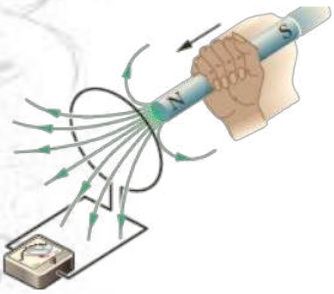
ⓒ a changing magnetic field induces an electric field

ⓓ magnetic flux is the product of the average perpendicular magnetic field and the area to it that it penetrates

6. Through the opposite shape:

1-On the drawing, determine the direction of the induced current if we move a bar magnet toward the loop .

2-If the movement of the magnet stops, what happens to the current induced by the loop?



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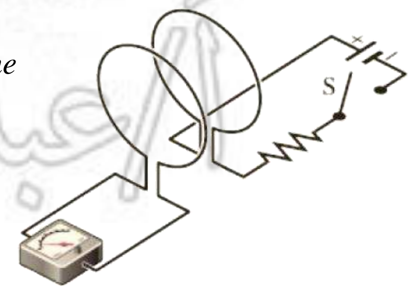
7. Through the opposite shape:

1-Determine the direction of the current in the two loops at the moment the circuit is closed only .

2- What happens to ameter reading after the circle is closed?



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Faraday's law of induction 2

A potential difference is induced in a loop when the number of magnetic field lines passing through the loop changes with time.
The rate of change of the magnetic field lines determines the induced potential difference.

- *means that the changing magnetic field actually creates an electric field around the loop.*
- *magnetic flux is defined as the surface integral of the magnetic field passing through a differential element of area :*

$$\phi_B = \iint B.dA$$

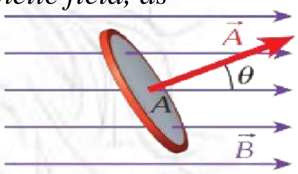
Where :

- ❖ *B is the magnetic field at each differential area element , dA of a closed surface .*
- ❖ *dA, always points out of the enclosed volume and is perpendicular to the surface everywhere.*

- *Integration of the magnetic flux over a closed surface field zero:*

$$\oiint B.dA = 0$$

- *Consider the special case of a flat loop of area A in a constant magnetic field, as illustrated in For this case, we can*

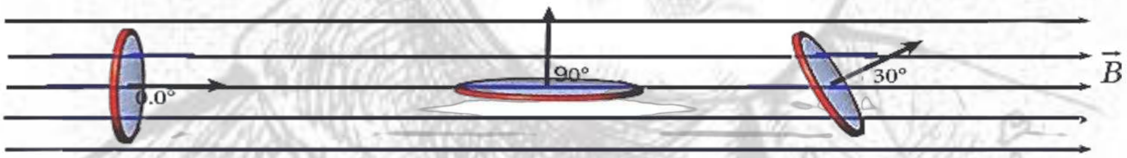


$$\phi_B = BA\cos\theta$$

weber (Wb): 1 Wb 1 = T m^2

B is the magnitude of the constant magnetic field
A is the area of the loop,
Θ is the angle between the surface normal vector to the plane of the loop and the magnetic field lines.

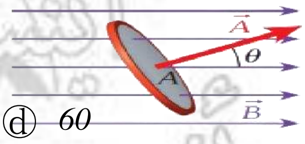
if the magnetic field is perpendicular to the plane of the loop, $\Theta = 0°$ and $\phi_B = BA$.
If the magnetic field is parallel to the plane of the loop, $\Theta = 90°$ and $\phi_B = 0$.



$\phi_B = BA\cos \mathbf{0} = BA$ $\phi_B = BA\cos \mathbf{90} = 0$ $\phi_B = BA\cos \mathbf{30}$

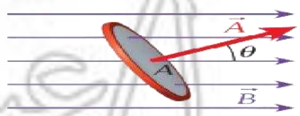
Check your understanding:

1. Depending on the shape, at what angle θ will the magnitude of the magnetic field will be (0.5AB)?



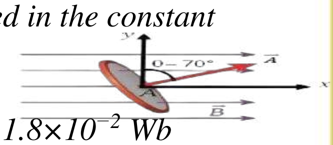
ⓐ *90* ⓑ *0* ⓒ *30* ⓓ *60*

2. *According to the figure, at which (θ) the magnetic flux equals approximately to(0.8AB)?*



ⓐ *90* ⓑ 37 ⓒ 53 ⓓ 74

3. *What is the magnetic flux through the loop of 4.2 cm radius, if it is placed in the constant field B=12 T as shown in the figure?*



ⓐ *2.3×10^{-2} Wb* ⓑ *4.5×10^{-2}Wb* ⓒ 6.2×10^{-2}Wb ⓓ *1.8×10^{-2} Wb*

4. What does the equation $\oint B \cdot dA = 0$ represent?
   - A. Magnetic field lines must form closed loops
   - B. Moving charges create magnetic field
   - C. There exist no magnetic monopoles
   - D. A and C

Faraday's Law of Induction is thus expressed by the equation

$$\Delta V_{ind} = -\frac{d\phi_B}{dt}$$

- The negative sign in equation is necessary because the induced potential difference establishes an induced current whose magnetic field tends to oppose the flux change

Lenz's Law

The magnetic flux can be changed in several ways

- including changing the magnitude of the magnetic field,
- changing the area of the loop,
- changing the angle, the loop makes with respect to the magnetic field.

In all situations that involve some form of motion of a conductor relative to the source of a magnetic field, the induced potential difference is called a motional emf.

induction in a Flat loop inside a Magnetic Field

- where uniform means that the field has the same value (same magnitude and same direction)

$$\Delta V_{ind} = -\frac{d\phi_B}{dt} = \frac{d}{dt}(BA\cos\Theta)$$

- We can use the product rule from calculus to expand this derivative:

$$\Delta V_{ind} = -A\cos\Theta\frac{dB}{dt} - B\cos\Theta\frac{dA}{dt} + AB\sin\Theta\frac{d\Theta}{dt}$$

- Because the time derivative of the angular displacement is the angular velocity, $\frac{d\Theta}{dt} = \omega$

$$\Delta V_{ind} = -A\cos\Theta\frac{dB}{dt} - B\cos\Theta\frac{dA}{dt} + \omega AB\sin\Theta$$

- Holding two of the three variables in equation (A, B, and Θ) constant results in the following three special cases:

- Holding the area of the loop and its orientation relative to the magnetic field constant but varying the magnetic field in time yields **A and Θ constant**

$$\Delta V_{ind} = -A\cos\Theta\frac{dB}{dt}$$

- Holding the magnetic field as well as the orientation of the loop relative to the magnetic field constant but changing the area of the loop that is exposed to the magnetic field yields **B and Θ constant**

$$\Delta V_{ind} = -B\cos\Theta\frac{dA}{dt}$$

- *Holding the magnetic field constant and keeping the area of the loop fixed but allowing the angle between the two to change as a function of time yields* **A and B constant**

$$\Delta V_{ind} = \omega AB \sin\theta$$

$$d\theta = \theta_F - \theta_I \quad , \quad d\boldsymbol{A} = \boldsymbol{A}_F - \boldsymbol{A}_I \quad , \quad d\boldsymbol{B} = \boldsymbol{B}_F - \boldsymbol{B}_I$$

Check your understanding:

1. *When can we use the following equation to find the induced potential difference?*

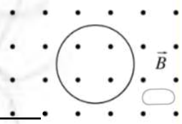
$$\Delta V_{ind} = -B\cos\theta \frac{dA}{dt}$$

ⓐ *A and B are constant* ⓑ *A, B, and θ are constant* ⓒ *θ and B are constant* ⓓ *A and θ are constant*

2. *When can we use the equation ($\Delta V_{ind}=\omega AB\sin\theta$) to find the induced potential difference?*

ⓐ *A and B are constant* ⓑ *A, B, and θ are constant* ⓒ *θ and B are constant* ⓓ *A and θ are constant*

3. *A uniform magnetic field vector B is directed out of the page, as represented below. A loop of wire of area 0.8 m^2 is in the plane of the page. At a certain instant, the field has a magnitude of 5.0 T and is decreasing at the rate of 0.5 T/s. The magnitude of the induced emf in the wire loop at this instant is most nearly ____.*

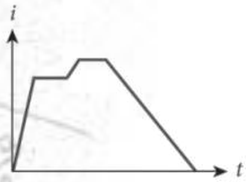


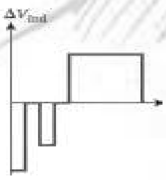
ⓐ *0.4 V* ⓑ *4.0 V* ⓒ *2.0 V* ⓓ *1.6 V*

4. *A solenoid with 200 turns has a cross-sectional area of 60 cm2. If the field is confined within the solenoid and changes at a rate of 0.20 T/s, what the magnitude of the induced potential difference in the solenoid?*

ⓐ *0.0020 V* ⓑ *0.001 V* ⓒ *0.24 V* ⓓ *0.02 V*

5. *A power supply is connected to loop 1 and an ammeter as shown in the figure. Loop 2 is close to loop 1 and is connected to a voltmeter. A graph of the current i through loop 1 as a function of time, t, is also shown in the figure. Which graph best describes the induced potential difference, ΔVind, in loop 2 as a function of time, t?*



ⓐ 

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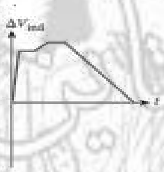
ⓒ 

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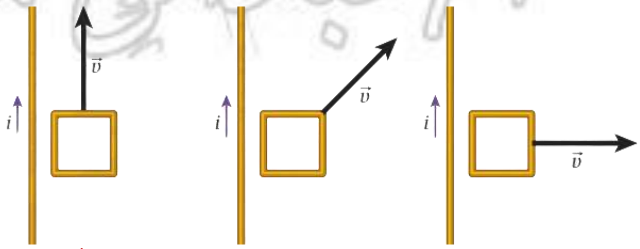
6. *A long wire carries a current, i, as shown in the figure. A square loop moves in the same plane as the wire as indicated. In which cases will the loop have an induced current?*

ⓐ *cases 1 and 2* ⓒ *cases 1 and 3*

ⓑ *cases 2 and 3* ⓓ *None of the loops will have an induced current.*



case 1 case 2 case 3

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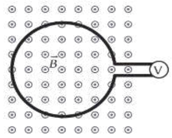
7. *The plane of the circular loop shown in the figure is perpendicular to a magnetic field with magnitude (B = 0.500 T). The magnetic field goes to zero at a constant rate in (0.250 s). The induced voltage in the loop is (ΔVind =1.24 V) during that time. What is the radius of the loop?*



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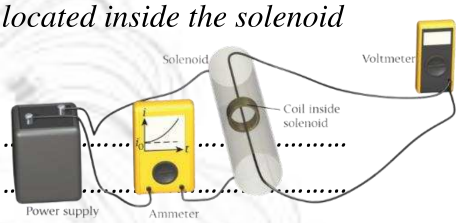
.... $r = 0.44m$

8. *A current of (600mA) is flowing in an ideal solenoid, resulting in a magnetic field of (B_0= 0.025 T). Then the current increases with time, t, according to* $i = i_0[1 + (2.4\ s^{-2})t^2]$
If a circular coil of radius (r= 3.4 cm) with (N =200 windings) is located inside the solenoid with its normal vector parallel to the magnetic field.
what is the induced potential difference in the coil at t = 2.0 s?



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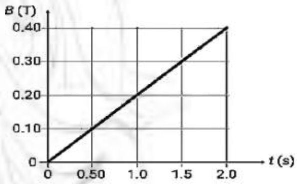
.... $\Delta Vind = -0.18\ V$

9. *A square loop of a side $1.0{\times}10^{-2}$m is placed in a magnetic field directed out of the plane of the screen so that B make θ=0º with the area vector, and whose magnitude varies according to the given graph.*
Determine the induced potential difference in the loop.



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.... $\Delta Vind = -2 \times 10^{-5} V$

10. *An 8 turn square loop whose side length is (0.20 m) is placed in a magnetic field that makes an angle of 40° with the normal to the plane of the loop. The magnitude of this field varies with time as:B(t) = -1.50 t³ where t is measured in s and B in T.*
    A. *What is the magnitude of the induced potential difference in the loop at (t = 2.0 s)?*
    B. *What is the magnitude of the induced current across the loop at (t = 2.0 s)?*

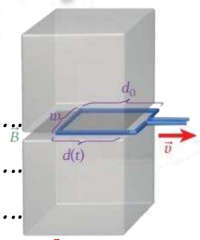
....

....

....

.... $\Delta Vind = 3.69\ V, i = 1.23\ A$

11. *A rectangular wire loop of width w = 3.1 cm and depth d0 = 4.8 cm is pulled out of the gap between two permanent magnets. A magnetic field of magnitude B = 0.073 T is present throughout the gap (Figure). If the loop is removed at a constant speed of 1.6 cm/s, what is the induced voltage in the loop as a function of time?*



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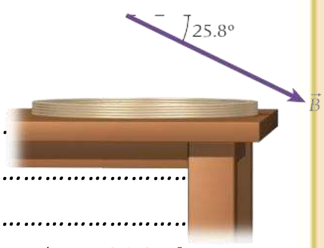
.... $\Delta Vind = 3.6 \times 10^{-5} V$

12. A circular coil of wire with (20 turns) and a radius of ($r= 40.0$ cm) is laying flat on a horizontal table as shown in the figure. There is a uniform magnetic field extending over the entire table with a magnitude of ($B= 5.00$ T) and directed to the north and downward, making an (angle of 25.8° with the horizontal).

What is the magnitude of the magnetic flux through the coil?

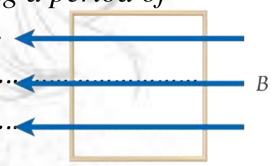


$\emptyset B = 21.9wb$

13. A respiration monitor has a flexible loop of copper wire, which wraps about the chest. As the wearer breathes, the radius of the loop of wire increases and decreases. When a person in the Earth's magnetic field ($B= 0.426 \times 10^{-4}$ T) inhales, what is the average current in the loop, assuming that it has a resistance of ($R= 30.0\ \Omega$) and increases in radius from ($r_1= 20.0$ cm to $r_2= 25.0$ cm) over ($\Delta t= 1.00$ s) ? Assume that the magnetic field is perpendicular to the plane of the loop.

$i = 1.00374 \times 10$

14. A metal loop has an area of 0.100 m^2 and is placed flat on the ground. There is a uniform magnetic field pointing west, as shown in the figure. This magnetic field initially has a magnitude of $B_1 = 0.123$ T, which decreases steadily to$B_2= 0.075$ T during a period of $t= 0.6$s. Find the potential difference induced in the loop during this time.



$\Delta Vind = 0V$

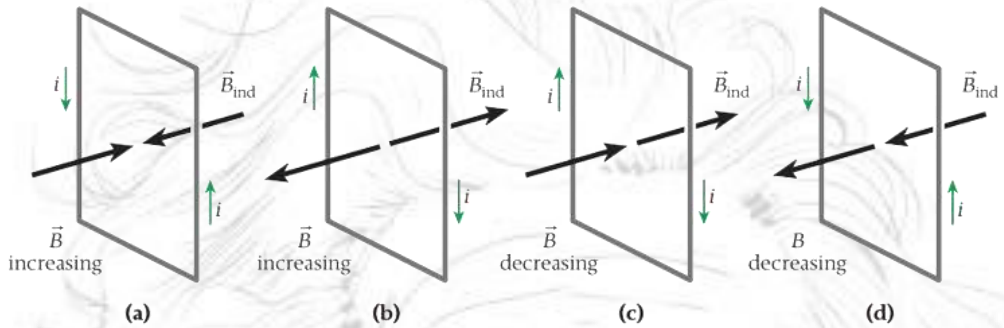
15. An 8-turn coil has square loops measuring ($L = 0.200$ m) along a side and a resistance of $R= 3.00\ \Omega$. It is placed in a magnetic field that makes an angle of (40.0°) with the plane of each loop. The magnitude of this field varies with time according to $B(t) = 1.50t^3$, where t is measured in seconds and B in Tesla.

What is the induced current in the coil at $t = 2.00$ s?

$i = 1.23A$

3 lenz's law

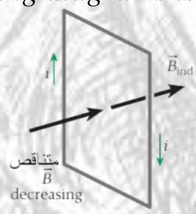
Lenz's Law provides a rule for determining the direction of an induced current in a loop.
" An induced current will have a direction such that the magnetic field due to the induced current opposes the change in the magnetic flux that induces the current"

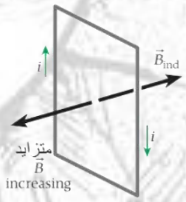


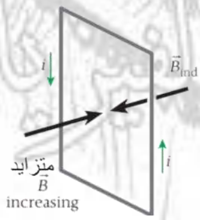
A. *An increasing magnetic field pointing to the right induces a current that creates a magnetic field pointing to the left. direction of current is counterclockwise*
B. *An increasing magnetic field pointing to the left induces a current that creates a magnetic field pointing to the right. direction of current is clockwise*
C. *A decreasing magnetic field pointing to the right induces a current that creates a magnetic field pointing to the right. direction of current is clockwise*
D. *A decreasing magnetic field pointing to the left induces a current that creates a magnetic field pointing to the left. direction of current is counterclockwise*

Check your understanding:

1. *Which of the following diagrams is not correct according to Lenz's Law?*

ⓐ


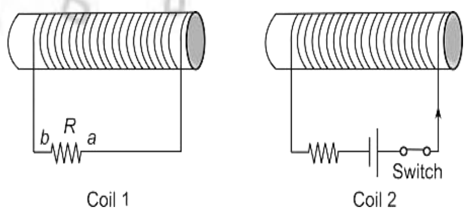
ⓒ


ⓑ


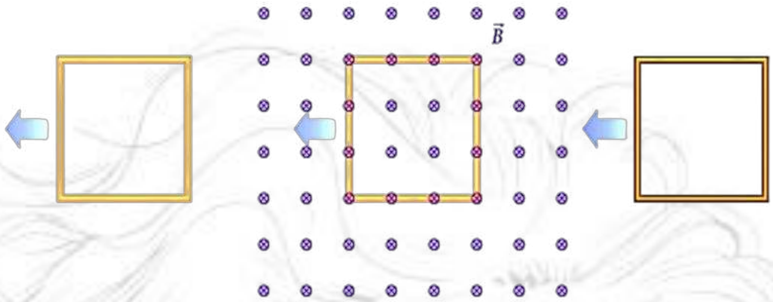
ⓓ


2. *Two coils are shown in the figure. Coil 2 has a current i flowing in the direction shown. When the switch in the circuit containing coil 2 is opened, what happens in coil 1?*

ⓐ *A current is induced in it that flows in two directions b to a and a to b.*
ⓑ *No current is induced in coil 1.*
ⓒ *A current is induced in it that flows in R from b to a.*
ⓓ *A current is induced in it that flows in R from a to b.*



3. A square conducting loop with very small resistance is moved at constant speed from a region with no magnetic field through a region of constant magnetic field and then into a region with no magnetic field, as shown in the figure. As the loop enters the magnetic field, what is the direction of the induced current? As the loop leaves the magnetic field, what is the direction of the induced current?



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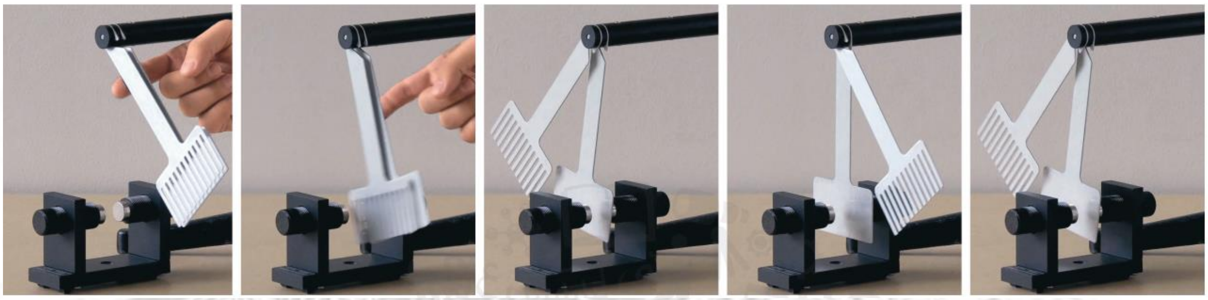
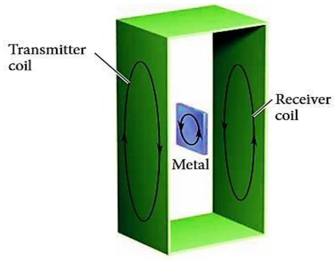
Eddy Currents

One metal plate is solid and the other has slots cut in it. The pendulums are pulled to one side and released. The pendulum with the solid metal plate stops in the gap, while the slotted plate passes through the magnetic field, only slowing slightly. This demonstration illustrates the very important phenomenon of induced eddy currents



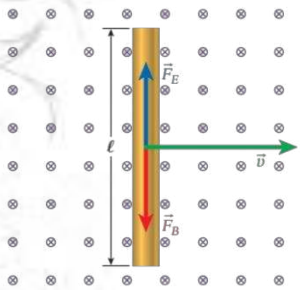
1. As the pendulum with the solid plate (1) enters the magnetic field between the magnets, these currents produce induced magnetic fields opposing the external field that created the currents.These induced magnetic fields interact with the external magnetic field (via their spatial gradients) to stop the pendulum.
2. Larger induced currents produce larger induced magnetic fields and thus lead to more rapid deceleration of the pendulum. In the slotted plate (2), the induced eddy currents are broken up by the slots, and the slotted plate passes through the magnetic field, only slowing slightly.
3. Eddy currents are often undesirable, forcing equipment designers to minimize them by segmenting or laminating electrical devices that must operate in an environment of changing magnetic fields. However, eddy currents can also be useful and are employed in certain practical applications, such as the brakes of train cars.

Metal Detector



A metal detector works by using electromagnetic induction, often called pulse induction.
A metal detector has a transmitter coil and a receiver coil. A transmitter coil and a receiver coil are located on opposite sides of an entry door. The person or object to be scanned passes through the door between the two coils. Suppose that the current in the transmitter coil is flowing in the direction shown and increasing. A current will be induced in the metal plate in the opposite direction and will tend to oppose the increase in the current in the transmitter coil. The increasing current in the metal plate will induce a current in the receiver coil that is in the opposite direction and tends to oppose the increase in the current in the metal plate (not shown in the diagram). Thus, the metal plate induces a current in the receiver coil that flows in the same direction as the current in the transmitter coil.
Without the metal plate, the increasing current in the transmitter coil induces a current in the opposite direction in the receiver coil that tends to oppose the increase in the current in the transmitter coil (as shown in the diagram). Thus, the overall effect of the metal plate in the metal detector is to decrease the observed current in the receiver coil. The metal object does not have to be a flat plate; any piece of metal, provided it is large enough, will have currents induced in it that can be detected by measuring the induced current in the receiver coil
Metal detectors are also used to control traffic lights.

induced Potential Difference on a Wire Moving in a Magnetic Field

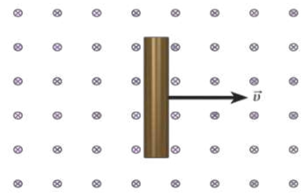


Consider a conducting wire of length L moving with constant velocity v perpendicular to a constant magnetic field, B, directed into the page.
The wire is oriented so that it is perpendicular to the velocity and to the magnetic field. The magnetic field exerts a force, FB, on the conduction electrons in the wire, causing them to move downward.
This motion of the electrons produces a net negative charge at the bottom end of the wire and a net positive charge at the top end of the wire.
This charge separation produces an electric field, E, which exerts a force, Fe, on the conduction electrons that tends to cancel the magnetic force.
After some time, the two forces become equal in magnitude (but opposite in direction) producing a zero net force: $F = evB$ $\quad F = eE$ $\quad E = vB$
Because the electric field is constant in the wire, it produces a potential difference between the two ends of the wire given by

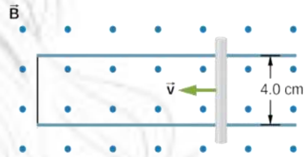
$$E = \frac{\Delta Vind}{L} = v\,B$$

The induced potential difference between the ends of the wire is then $\Delta Vind = v\,LB$

1. *A metal bar is moving with constant velocity v through a uniform magnetic field pointing into the page, as shown in the figure.*
Which of the following most accurately represents the charge distribution on the surface of the metal bar?

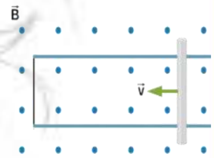


2. *The conducting rod shown in the figure, is pulled horizontally through a uniform magnetic field of strength (B=0.65T) with a constant velocity. If the induced potential difference between the ends of the rod equals to (0.32V). What is the velocity of the rod?*



ⓐ 9.81m/s ⓑ 12.3m/s ⓒ 0.08m/s ⓓ 2.08m/s

3. *A conducting rod is pulled horizontally by a constant force of magnitude, (F = 5.00 N,) along a set of conducting rails separated by a distance (a = 0.500 m) (Figure). The two rails are connected, and no friction occurs between the rod and the rails. A uniform magnetic field with magnitude (B = 0.500 T) is directed into the page. The rod moves at constant speed, (v =5.00 m/s).*
What is the magnitude of the induced potential difference in the loop created by the connected rails and the moving rod?



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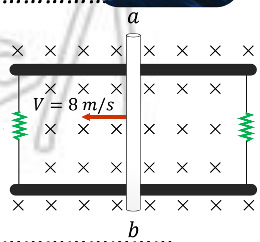
$\Delta Vind = 1.25V$

4. *In 1996, the Space Shuttle Columbia deployed a tethered satellite on a wire out to a distance of 20 km, The wire was oriented perpendicular to the Earth's magnetic field at that point, and the magnitude of the field was (B = 5.1 × 10–5 T) . Columbia was traveling at a speed of (7.6 km/s).*
What was the potential difference induced between the ends of the wire?

....

$\Delta Vind = 7800V$

5. *A conducting rod of length 50.0 cm slides over two parallel metal bars placed in a magnetic field with a magnitude of 0.1 T, as shown in the figure.*
The ends of the rods are connected by two resistors, R_1 = 100Ω and R_2 = 200Ω.
The conducting rod moves with a constant speed of 8.00 m/s
What are the currents flowing through the two resistors?



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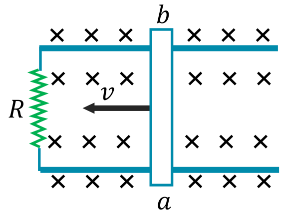
$\Delta Vind = 0.4V, i_1 = 4 \times 10^{-3}A, i_2 = 2 \times 10^{-3}A$



as shown in the figure a conductor(a, b) of length 0.2 m that slides to the left on two wires without friction at a constant speed of 0.4m / s vertically on a regular magnetic field in which an induced electric force is generated its amount 0.1V, Answer the following:

1. *The amount of intensity of the magnetic field in which the conductor moves*
2. *What is the magnitude of the induced current through the resistance R (4 Ω) and determine the Direction of the current on the resistance.*
3. *In which direction the wire can be moved so that no induced electromotive force is Generated .*

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4 Generators and Motors

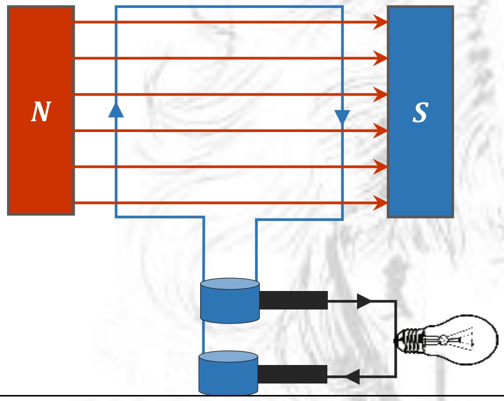
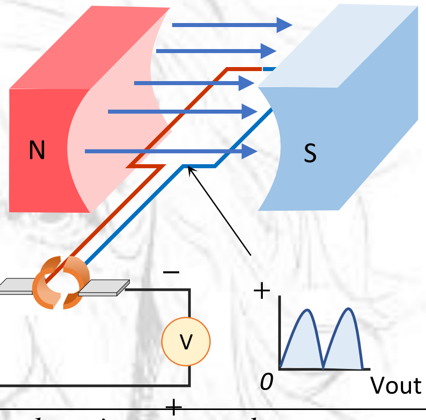
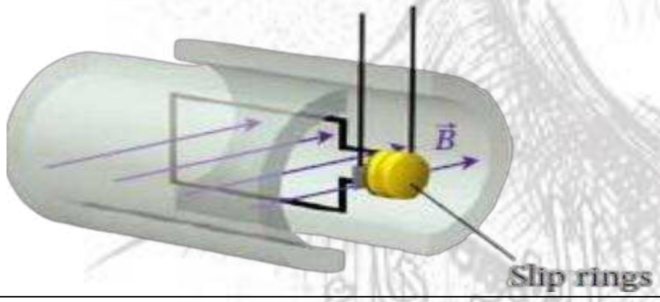
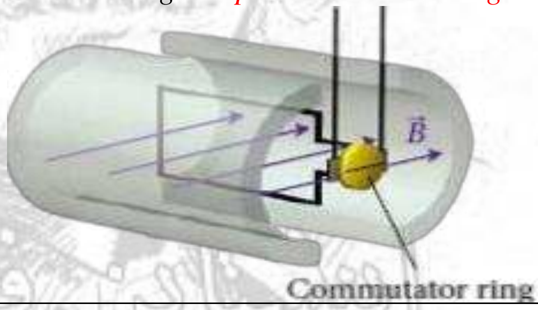
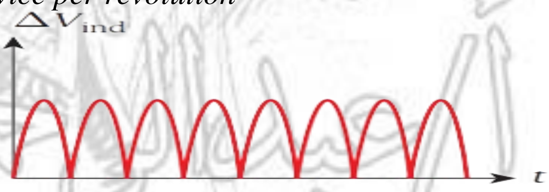
Electric generator: (Converts electrical energy into kinetic energy)

A device that produces electric current from mechanical motion is called an electric generator.

Electric motor: (Converts mechanical energy into electrical energy)

A device that produces mechanical motion from electric current is called an electric motor

A simple generator consists of a loop forced to rotate in a fixed magnetic field.
The force that causes the loop to rotate can be supplied by hot steam running over a turbine, as occurs in nuclear and coal-fired power plants.
(Power plants actually use multiple loops in order to increase the power output.)
On the other hand, the loop can be made to rotate by flowing water or wind to generate electricity in a pollution-free way.

Alternating current generator (AC)	***Direct-current generator (DC)***
	
Each end of the loop is connected to the external circuit through its own solid slip ring	*The rotating loop is connected to an external circuit through a split commutator ring*
	
An alternating current is a current that varies in time between positive and negative values	*As the loop turns, the connection is reversed twice per revolution*
	
the generator produces an induced potential difference that varies from positive to negative and back	*the induced potential difference always has the same sign*

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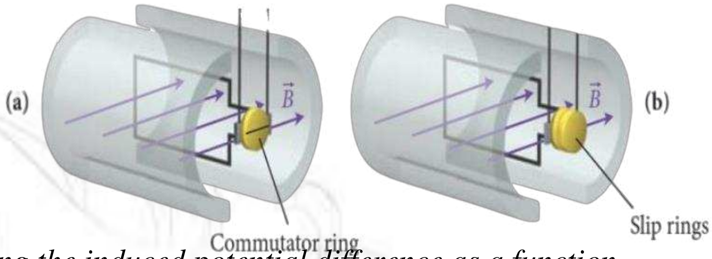
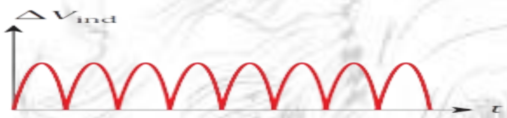
Check your understanding:

1. The figures (a) and (b) below shows two types of simple generators.

	Figure (a)	Figure (b)
A.	DC generator	AC generator
B.	DC generator	DC generator
C.	AC generator	DC generator
D.	AC generator	AC generator



2. The figure shows two graphs representing the induced potential difference as a function of time for two generators.
   Which of the following rows indicates the correct type of generator under each graph?

	Figure (a) 	Figure (b) 
A.	a simple direct-current generator	a simple alternating-current generator
B.	a simple alternating-current generator	a simple direct-current generator
C.	a simple alternating-current generator	a simple alternating-current generator
D.	a simple direct-current generator	a simple direct-current generator

3. Which of the following is not correct about the generator and motors?

ⓐ The motors transform kinetic energy into electric energy

ⓑ Generators and motors are applications of electromagnetic induction

ⓒ Generator that produce alternating voltages and the resulting alternating current is also called an alternators

ⓓ Generators and motors contain loops in a magnetic field

4. Which of the following is correct about the generator and motors?

ⓐ The motors transform kinetic energy into electric energy

ⓑ Generators and motors are not applications of electromagnetic induction

ⓒ Generator that produce alternating voltages and the resulting alternating current is also called an alternators

ⓓ Generators contain loops in a magnetic field but motors do not contain loops in a magnetic field

regenerative braking

Hybrid cars are propelled by a combination of gasoline power and electrical power. One attractive feature of a hybrid vehicle is that it is capable of regenerative braking. When the brakes are used to slow or stop a nonhybrid vehicle, the kinetic energy of the vehicle is turned into heat in the brake pads. This heat dissipates into the environment, and energy is lost. In a hybrid car, the brakes are connected to the electric motor , which functions as a generator, charging the car's battery. Thus, the kinetic energy of the car is partially recovered during braking, and this energy can later be used to propel the car, contributing to its efficiency and greatly increasing its gas mileage in stop-and-go driving.

5 induced electric Field

Consider a positive charge q moving in a circular path with radius r in an electric field E. The work done on the charge is equal to the integral of the scalar product of the force and the differential displacement vector

$$W = \oint F.ds = \oint Eq.ds$$

$$W = \oint q\cos 0 .Eds = Eq\oint ds = qE\ (2\pi r)$$

Since the work done by a constant electric field is ΔV_{ind} , q we get

$$\Delta Vind = 2\pi rE$$

Now we can express the induced potential difference in a different way

$$\Delta Vind = \oint E.ds = -\frac{d\emptyset_B}{dt}$$

Check your understanding:

1. *For a positive charge moving in a circular path in an electric field, the induced potential difference can be expressed as (ΔVind=2πxE). What does x represent?*

ⓐ *The radius of the circular path* ⓑ *Induced electric field* ⓒ *The magnitude of the charge* ⓓ *Induced electric current*

2. *For a positive charge moving in a circular path in an electric field the work done can be expressed as (W=2πrxE). What does x represent?*

ⓐ *The radius of the circular path* ⓑ *Induced electric field* ⓒ *The magnitude of the charge* ⓓ *Induced electric current*

inductance of a Solenoid :

Consider a long solenoid with N turns carrying a current, i. This current creates a magnetic field in the center of the solenoid, resulting in a magnetic flux, ϕB.
The same magnetic flux goes through each of the N windings of the solenoid.

$$N\,\Phi B = L\,i$$

L,called the inductance The unit of inductance is the henry (H)
ΦB called The flux linkage for this solenoid is The unit of flux is wb =$T.m^2$

$$L = \frac{N\,\Phi B}{i}$$

$$(H) = \frac{T.m^2}{A}$$

$$(H \approx V.S/A \approx Wb/A)$$

n is the number of turns per unit length $n = \frac{N}{L}$

$$N\,\Phi B = (nl)(BA)$$

"B is the magnitude of the magnetic field inside the solenoid sectional area A and length ℓ"

$$L = \frac{\mu_\circ A N^2}{l} = \mu_\circ A\, nl$$

$\mu_\circ$:*the magnetic permeability of free space* $\mu_\circ = 4\pi \times 10^{-7}\ H/m$

•You can see from equation that the inductance of a solenoid depends only on the geometry (length(l), area(A), and number of turns (N) of the device.
•Any solenoid has an inductance, and when a solenoid is used in an electric circuit, it is called an inductor, simply because its inductance is its most important property as far as the current flow is concerned

Check your understanding:

1. *Which of the following is not correct unit of magnetic flux?*

ⓐ H.A ⓑ $T.m^2$ ⓒ V.s ⓓ H.A/s

2. *What does the unit of inductance Henry (H) equal?*

ⓐ Tm^2\A ⓑ Am^2\T ⓒ A^2m^2\T ⓓ T^2m\A

3. *Which of the following is not a unit of inductance Henry (H) equal?*

ⓐ $\frac{Tm^2}{A}$ ⓑ H ⓒ $\frac{V.A}{S}$ ⓓ $\frac{V.S}{A}$

4. *A solenoid's inductance is equal to (L). Suppose that the length of the solenoid is reduced to half its original length, and the average cross-section radius is increased to be double, while the number of turns remains unchanged. How much the inductance becomes?*

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ⓐ 4L ⓑ L ⓒ l\2L ⓓ 2L

5. *Which of the following has the largest inductance?*

A.	*A solenoid of radius 1 cm, length 5 cm, and with 100 turns of wire per centimeter*
B.	*A solenoid of radius 3 cm, length 1 cm, and with 100 turns of wire per centimeter*
C.	*A solenoid of radius 2 cm, length 2 cm, and with 100 turns of wire per centimeter*
D.	*A solenoid of radius 2 cm, length 5 cm, and with 100 turns of wire per centimeter*

NOTE

6. *Calculate the inductance of an air-core solenoid containing 300 turns if the length of the solenoid is 25.0 cm and its cross-sectional area is 4.00 cm^2.*

$L=0.181$ mH

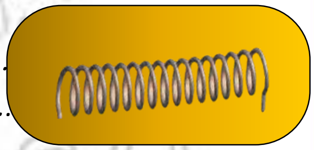
7. *Solenoid coil of 20 cm length and section area of 20 cm^2. his number of turn is 300 turns It is upset from the air and passed through a 4 A electric current Calculate the magnetic flux that passes the coil section .*

$\Phi B = 1.51\times10^{-5}$Wb

8. *Solenoid has (600) turns and cross section area (4.0 × 104 m^2) its core from air and inductance (0.40H) a current of its intensity passes through it(0.50A)*
Calculate length of Solenoid

$l=4.52\times10^{-4}$m

9. *A solenoid's inductance is equal to (3.0×10^{-3} H). Suppose that the length of the solenoid is increased to be three times its original length, and the average cross-section area is reduced to be one fifth of its original radius, while the number of turns reunchanged. Calculate the new inductance*



$L=4\times10^{-5}$H

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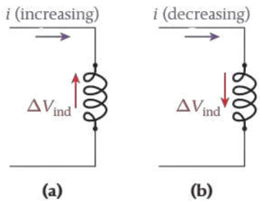
1. *Self-Induction*

self-induction "The changing current in the first coil also induces a potential difference in that coil, and thus the magnetic field from that coil also changes."

(a) Self-induced potential difference in an inductor when the current is increasing.

(b) Self-induced potential difference in an inductor when the current is decreasing.

According to Faraday's Law of Induction the self-induced potential difference for any inductor is given by



$$\Delta Vind = -\frac{d(N\emptyset_B)}{dt} = -\frac{d(IL)}{dt} = -L\frac{dI}{dt}$$

$d\Phi = \Phi_f - \Phi_i$

$di = i_f - i_i$

Unit $V = \frac{H.A}{S}$ *Henry (H) is=* $\frac{V.S}{A}$

Check your understanding:

1. *A 5.6 mH inductor is connected to a current source. What is the magnitude of the voltage in the inductor at time* $t = 4.0$ *s if the current is* $I(t) = 10.0 + 9.0t - 3.0t^2$*?*

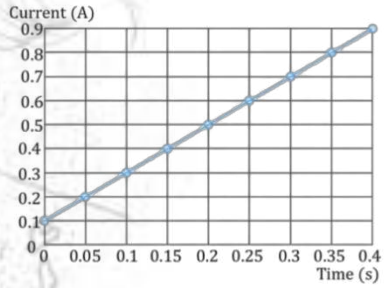
ⓐ 11 mV ⓑ 58 mV ⓒ 84 mV ⓓ 22 mv

2. *A inductor has an inductance of 4.0 mH. To generate an emf of 2.0 V the current should change at a rate of……*

ⓐ 500 A/s ⓑ 50 A/s ⓒ 250 A/s ⓓ 0.5 A/s

3. *A 75 H inductor has s time-dependent current flowing through it over a short period of time as shown in the graph below.*

What is the magnitude of the emf induced by the inductor at time $t = 0.3$ *s?*



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ⓐ 22.5 V ⓑ 150 V ⓒ 67.5 V ⓓ 7.5 V

4. *A 1.0 A current passes through a 10 mH inductor coil. What potential difference is induced across the coil if the current drops to zero in 5.0* μs*?*

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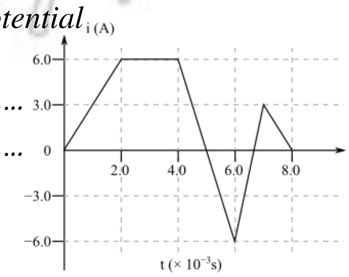
…………………………………………………………………… $\Delta V = 2000$ V

5. *The graph shows the current through a 12mH inductor. What is maximum potential difference* $V_{L(ind)}$ *induced in the inductor over the period shown?*



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ⓐ 36V ⓑ 72V ⓒ 108V ⓓ 144V

2. *Mutual Induction :*

It occurs between two coils close to each other

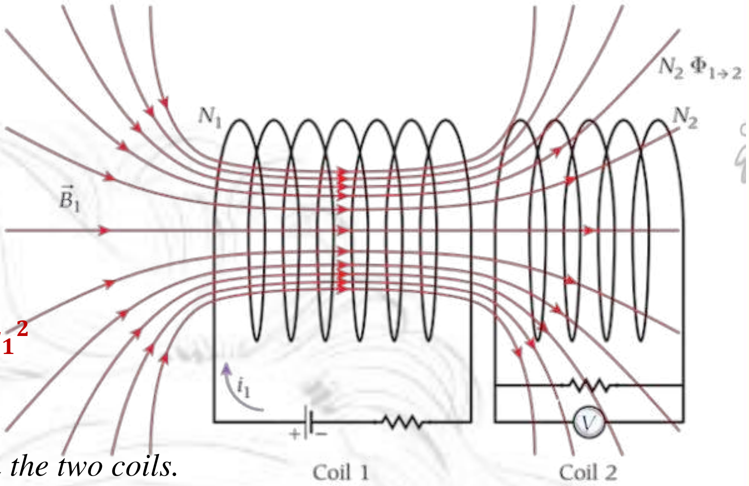
Changing the current in the first coil also induces a potential difference in the second coil.

$$\Delta Vind,2 = -M_{1-2}\frac{dI_1}{dt}$$

$$\Delta Vind,1 = -M_{2-1}\frac{dI_2}{dt}$$

$$M_{1-2} = M_{2-1}$$

$$M = \frac{NBA}{i} = \frac{N(\mu_\circ ni)(\pi r_1{}^2)}{i} = N\pi\mu_\circ nr_1{}^2$$



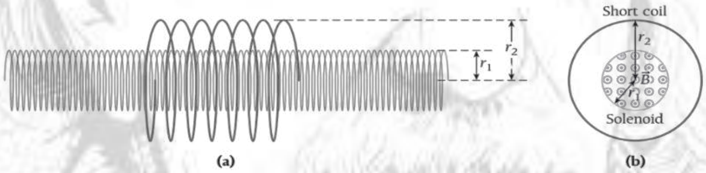
where M is the mutual inductance between the two coils.

The SI unit of mutual inductance is the henry.

Check your understanding:

1. *A long solenoid with a circular cross section of radius (r_1=0.05m) and (n-800turns/m) is inside and coaxial with a short coil that has a circular cross section of radius (r_2 =0.10m) and (N=7turns). While the current in the long solenoid is increased steadily from (0.003A) to / over (0.6millisecond), the potential difference induced in the short coil is (-0.4V).*

   Calculate the current I



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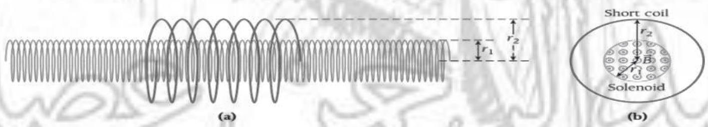
i_f = 4345A

A long solenoid with circular cross section of radius (r1 = 2.80 cm) and (n = 290 turns/cm) is inside and coaxial with a short coil with circular cross section of radius (r2 = 4.90 cm) and(N = 31 turns), The current in the solenoid is increased at a constant rate from zero to (i = 2.20 A) over a time interval of (Δt= 48.0 ms) .

2. *What is the potential difference induced in the short coil while the current is changing?*



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$\Delta Vind = -0.128V$

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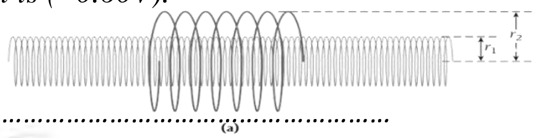
3. A long solenoid with a circular cross section of radius (r_1=4.0cm) and (n=300turns/cm) is inside of and coaxial with a short coil that has a circular cross section of radius(r_2=6.0cm) and (N=50turns). While the current in the long solenoid is increased steadily from (0.27A) to (i)in (20.0ms), the potential difference induced in the short coil is (- 0.60V).
What is the magnitude of the current (i)?



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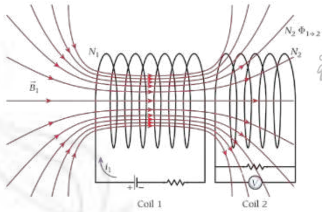
.... i_f = 1.54A

4. depending on the figure, what does symbol z represent in the equation

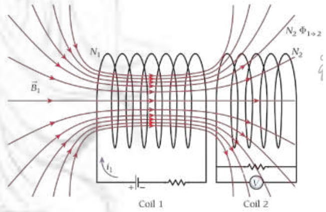
$$\Delta Vind,2 = -Z\frac{dI_1}{dt}$$



ⓐ the turns for coil 1 N_1 ⓑ the inductance for coil 1 L_1 ⓒ The inductance for coil 2L_2 ⓓ the mutual inductance between the two coils M.

5. depending on the figure, what does symbol z represent in the equation

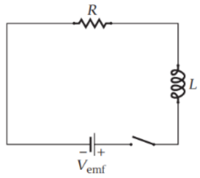
$$Z = -\frac{\Delta Vind,2}{(\frac{dI_1}{dt})}$$



ⓐ the turns for coil 1 N_1 ⓑ the inductance for coil 1 L_1 ⓒ The inductance for coil 2L_2 ⓓ the mutual inductance between the two coils M.

8 RL CIRCUIT

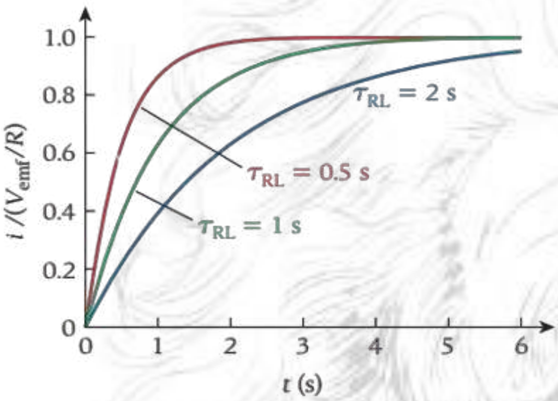
- *If a source of emf is placed in a single-loop circuit containing a resistor with resistance R and an inductor with inductance L, called an RL circuit, a similar phenomenon occurs. Figure shows a circuit in which a source of emf is connected to a resistor and an inductor in series.*

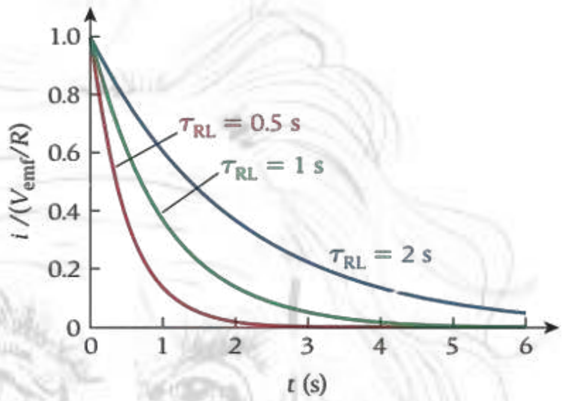


The quantity L/R is the time constant of the RL circuit: $\tau = \frac{1}{LR}$

for t = 0, the current is zero.

for t →∞, the current is given by $i = \frac{Vemf}{R}$





which is as expected. Now consider the circuit depicted in Figure, in which a source of emf was first connected and then suddenly removed. We can use equation with Vemf = 0 to describe the time dependence of this circuit: $L\frac{di}{dt} + = IR = 0$

$$i(t) = i0\ e^{-t/\tau RL}$$

1. *Which of the following is wrong regarding the time constant (T) in RL circuit?*

ⓐ *The time constant increases as the resistance decreases*
ⓑ *The time constant decreases as the resistance increases*
ⓒ *The time constant decreases as the inductance increases*
ⓓ *The time constant decreases as the inductance decreases*

2. *Which of the following is true regarding the time constant (T) in RL circuit?*

ⓐ *The time constant decreases as the resistance increases*
ⓑ *The time constant increases as the resistance increases*
ⓒ *The time constant decreases as the inductance increases*
ⓓ *The time constant does not change with the change of inductance*

3. *Consider an RL circuit with resistance R = 1.00 MΩ and inductance L = 1.00 H, which is powered by a 10.0 V battery.*
   a. *What is the time constant of the circuit?*
   b. *If the switch is closed at time t = 0, what is the current just after that time?*
   c. *What is the current when a long time has passed?*

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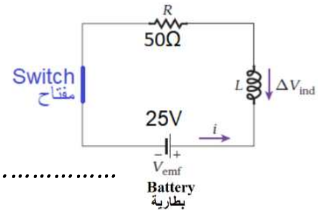
4. According to the figure that shows closed circuit for a long time, if the circuit is opened, what is the current in the circuit when time is equal to the time constant (from the moment the circuit is opened)?



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.... I=. 0.18 A

9.9 Energy and energy Density of a Magnetic Field

We can think of an inductor as a device that can store energy in a magnetic field

$$P = Vemf\ i = (L\frac{di}{dt})i$$

Now let's consider an ideal solenoid with length l, cross-sectional area A, and n turns per unit length, carrying current i. The energy stored in the magnetic field of the solenoid using is

$$U_B = \int Pdt = \frac{1}{2}Li^2 = \frac{1}{2}\mu_\circ n^2\ lA\ i^2$$

The magnetic field occupies the volume enclosed by the solenoid, which is given by lA. Thus, the energy density, uB, of the magnetic field of the solenoid is

Since $B = \mu_0 ni$ for a solenoid, the energy density of the magnetic field of a solenoid can be expressed as

$$U_B = \frac{1}{2\ \mu_\circ}B^2$$

5. If the current is doubled, what happens to the energy stored in the solenoid?

❒ decreases by a factor of 4 ❒ decreases by a factor of 2
❒ increases by a factor of 4 ❒ increases by a factor of 2

6. A long solenoid has a circular cross section of radius $r = 8.10\ cm$, a length $l = 0.540\ m$, and $n = 2.00 \times 10^4\ turns/m$. It has a current of 4.04×10^{-3} A flowing through it.
What is the energy stored in the solenoid?

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7. A long solenoid has a circular cross section of radius (9.0cm), and length (17.0cm). The number of turns in one meter for the solenoid is ($3.2x10^3$) and it carries a current (0.5A).
Calculate the magnetic energy stored in the solenoid.

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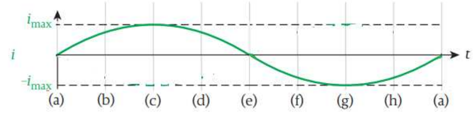
8. In the equation below, which of the following is a correct unit for uB?

ⓐ $J.m^{-3}$ ⓑ $J.m^{-2}$ ⓒ $J.s^{-1}$ ⓓ J

9. . The figure shows the variation of current as a function of time for a simple, single-loop LC circuit. If the maximum value of magnetic energy is (16.0milli-Joule)
what is the magnetic energy at time (g)?



10. *The total amount of energy stored in an RL series circuit is 8.0 J. When the current through the inductor is equal to half its value*($\frac{Im}{2}$) *maximum value how much energy is stored in the magnetic field?*

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