اسألني عن
الفيزياء2

إعداد: عمر الحمري

اسألني عن الهندسة

CHAPTER 29:

ELECTROMAGNETIC INDUCTION

Electromagnetic induction:

يتولد التيار الحثي عن طريق:
1) التغيير في التدفق المغناطيسي.
2)غمر موصل في مجال مغناطيسي ثم سحبه بسرعة ثابتة.

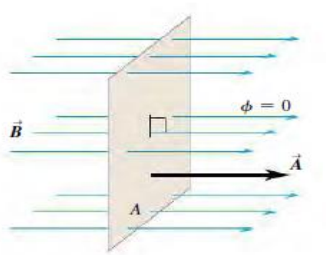
❖ **magnetic flux: (التدفق المغناطيسي):**

التدفق المغناطيسي: عدد خطوط المجال المغناطيسي التي تخترق سطحا ما عموديا عليه.

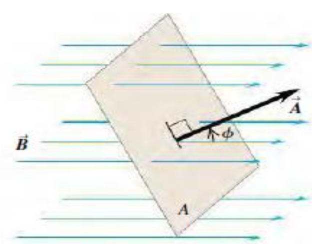
$$\phi_B = \vec{B} \cdot \vec{A} = B * A * cos\phi$$

Where:
ϕ_B: magnetic flux.
$\vec{A}$: $(+\hat{k}, +\hat{j}, +\hat{i})$ متجه المساحة وهو العامودي على السطح ويفضل أن يكون بالاتجاه الموجب
A: the area.
ϕ: the angle between $(\vec{B}\ and\ \vec{A})$.

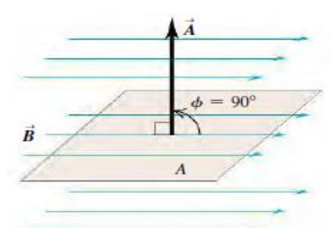
**وحدة التدفق المغناطيسي: (weber)



(a)



(b)



(c)

$\phi = 0^{\circ}$
$\phi_B = \vec{B} \cdot \vec{A}$
$\phi_B = B * A * cos0^{\circ}$
$\phi_B = B * A$

$\phi = \phi$
$\phi_B = \vec{B} \cdot \vec{A}$
$\phi_B = B * A * cos\phi$

$\phi = 90^{\circ}$
$\phi_B = \vec{B} \cdot \vec{A}$
$\phi_B = B * A * cos90^{\circ}$
$\phi_B = 0$

يمكن تغيير التدفق المغناطيسي من خلال التغيير في:

$$\phi_B = B * A * cos\phi$$

1)التغير في المجال المغناطيسي(B) 2)التغيير في المساحة(A) 3)التغيير في الزاوية(ϕ)

❖ Faraday's Law:

إن التيار المتولد في الملف نتيجة التغير في التدفق المغناطيسي يسمى تيارا حثيا وهذا التيار لحظي ينتج من قوة دافعة كهربائية تسمى قوة دافعة كهربائية حثية تتولد في الملف بسبب التغير في التدفق المغناطيسي وتسمى هذه الظاهرة ظاهرة الحث الكهرومغناطيسي (Electromagnetic induction).

ينص قانون فارادي:
على أن متوسط القوة الدافعة الكهربائية الحثية المتولدة في الملف (The induced emf) يتناسب طرديا مع المعدل الزمني لتغيير التدفق المغناطيسي الذي يختزنه.

$$\mathcal{E} = -\frac{d\Phi_B}{\mathrm{dt}}$$

Where:

$\mathcal{E}$: The induced emf in a closed loop (القوة الدافعة الكهربائية الحثية).

$\frac{d\Phi_B}{\mathrm{dt}}$: the time rate of change of magnetic flux through the loop

**الإشارة السالبة ستفسر لاحقا عند دراسة قانون لنز.

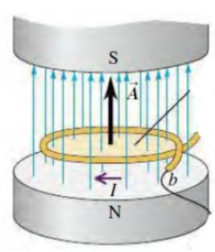
$$I = \frac{\mathcal{E}}{R}$$

Where:
I: induced current (التيار الحثي).
R: resistance(المقاومة).

Example (1): The magnetic field between the poles of the electromagnet is uniform at any time, but its magnitude is increasing at the rate of 0.020 T/s. The area of the conducting loop in the field is 120 cm^2, and the total circuit resistance, including the meter, is (5.0 Ω). Find the induced emf and the induced current in the circuit.

Solution:

$\frac{d\Phi_B}{\mathrm{dt}} = 0.020\ \mathrm{T/s}$ A=120 cm^2 R=5.0 Ω $\phi = 0^{\circ}$



$$\mathcal{E} = -\frac{d\Phi_B}{\mathrm{dt}} = -\frac{d(B*A*COS(\phi))}{dt} = -A*\frac{dB}{dt}*COS(\phi) = 120*10^{-4}*0.020 = 0.24\ mV$$

$$I = \frac{\mathcal{E}}{R} = \frac{0.24*10^{-3}}{5} = 0.048\ mA$$

❖ Direction of induced emf:

1)تحديد متجه المساحة وهو العامودي على السطح ويفضل أن يكون بالاتجاه الموجب$(+\hat{k},+\hat{j},+\hat{i})$.

2)تحديد اتجاه المجال المغناطيسي $(\vec{B})$ وتحديد إشارة التدفق المغناطيسي (ϕ_B) ومعدل التغير (متناقص أو متزايد) $(\frac{d\phi_B}{dt})$.

3) تحديد إشارة التيار الحثي (induced current) (I) والقوة الدافعة (induced emf) $(\mathcal{E})$عن طريق:

a) اذا كان التدفق المغناطيسي متزايد (ϕ_B) اذا $(\frac{d\phi_B}{dt})$ موجب اذا $(\mathcal{E}$ و $I)$ سالب.

b) اذا كان التدفق المغناطيسي متناقص (ϕ_B) اذا $(\frac{d\phi_B}{dt})$ سالب اذا $(\mathcal{E}$ و $I)$ موجب.

4) تطبيق قاعدة اليد اليمنى عن طريق:
الابهام باتجاه متجه المساحة والاصابع باتجاه التيار الحثي إذا كانت موجبة وإذا كانت سالبة فبعكس اتجاه الأصابع.

إذا كان الملف عبارة عن (coil) عدد من اللفات نستخدم هذا القانون لإيجاد (induced emf):

$$\mathcal{E} = -N\frac{d\phi_B}{dt}$$

Example (2): A 500-loop circular wire coil with radius 4.00 cm is placed between the poles of a large electromagnet. The magnetic field is uniform and makes an angle of 60° with the plane of the coil; it decreases at 0.200 T/s. What are the magnitude and direction of the induced emf?

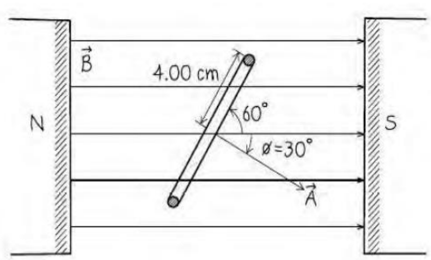
Solution: N=500turns A=$\pi * r^2 = \pi * (4*10^{-2})^2 = 16\pi * 10^{-4}$m

$\frac{dB}{dt} = -0.2 \ (decreases)$

$\phi = 30^\circ$ *(The angle between $\vec{B}$ AND $\vec{A}$,not the angle between $\vec{B}$ and the plane of the loop)*

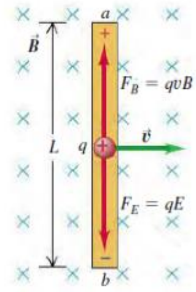
$\mathcal{E} = -N * A * \frac{dB}{dt} * COS(\phi) = -500 * 16\pi * 10^{-4} * (-0.2\ )\mathcal{E} = +\ 0.435V$

the direction of ($\mathcal{E}$ و I) would be clockwise.



❖ Motion Induced Electromotive Force:

غمر موصل مستقيم طوله (L) في مجال مغناطيسي منتظم ($\vec{B}$) ويسحب بسرعة ثابتة ($\vec{V}$) بتأثير قوة خارجية فإن الشحنات الموجبة على الموصل ستتأثر بقوة مغناطيسية، مما يجعل الشحنات تتحرك داخل الموصل من (B→A) وفقا لقاعدة اليد اليمنى فتتراكم الشحنات الموجبة عند الطرف (A) والسالبة عند الطرف (B) فينشأ مجال كهربائي فينشأ تيار حثي (induced current) من (B→A).



**$\mathcal{E} = LVB$

Where:
$\mathcal{E}$: the motional emf

For any closed conducting loop, the total emf: حالة خاصة:

$$\mathcal{E} = LVB \oint (\vec{V} \times \vec{B}) \cdot \vec{dl}$$

**$I = \frac{\mathcal{E}}{R} = \frac{LVB}{R}$

Where:
I: induced current

**$p_{dissipated} = I^2 * R = \frac{L^2V^2B^2}{R}$

Where:
$p_{dissipated}$: power dissipated.

**Magnetic force:
$F = I(\vec{L} \times \vec{B}) = ILBsin\emptyset$

Where:
$\emptyset$: the angle between L and B.

$$F = ILB = \frac{L^2B^2V}{R}$$

$$p_{applied} = F * V = \frac{L^2V^2B^2}{R}$$

Example (3): Suppose the moving rod is (0.10 m) long, the velocity v is (2.5 m/s), the total resistance of the loop is (0.030 Ω), and B is 0.60 T. Find the motional emf, the induced current, and the force acting on the rod.

Solution: L = 0.10 m V=2.5 m/s R= 0.030 Ω B=0.60 T

$$\mathcal{E} = L * V * B = 0.1 * 2.5 * 0.6 = 0.15v$$

$I = \frac{\mathcal{E}}{R} = \frac{0.15}{0.03} = 5A$

$F = \text{ILB} = 5 * 0.1 * \ 0.6 = 0.3\ N$

❖ لحساب المجال الكهربائي:

$$\oint \vec{E} \, . \vec{dl} \ = -\frac{d\phi_B}{\text{dt}} = \mathcal{E}$$

ملاحظة: $(\oint \vec{dl})$ تساوي الطول أو محيط الدائرة.

Example (4): Suppose the long solenoid in Fig. 29.18a has 500 turns per meter and cross-sectional area 4.0 cm^2. The current in its windings is increasing at 100 A/s. (a) Find the magnitude of the induced emf in the wire loop outside the solenoid. (b) Find the magnitude of the induced electric field within the loop if its radius is 2.0 cm.

Solution: n =500 A=4.0 cm^2 $\frac{dI}{dt}$ = 100 (A/s)

a)

$\mathcal{E} = -\frac{d\phi_B}{\text{dt}} = -\frac{d(B*A)}{\text{dt}} = -\frac{dI}{\text{dt}} * A * n * \mu_\circ$

B of solenoid: $B = In\mu_\circ$

$\mathcal{E} = \ -100 * (4 * \ 10^2) * 500 * (4\pi * \ 10^{-7}) \ = \ -25\mu\, v$

b)

$\oint \vec{E} \, . \vec{dl} \ = \mathcal{E}$

$E * 2\pi r = \mathcal{E}$

$E = \frac{-25 * 10^{-6}}{2\pi * 2 * 10^2} = 2 * \ 10^{-4}\, (V/m)$

$\oint dl$: $(2\pi r)$ تساوي محيط الدائرة

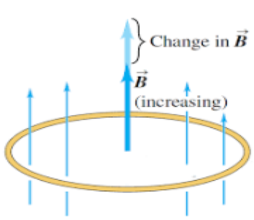
❖ Lenz's Law:

ينص قانون لنز:
اتجاه التيار الحثي في الملف يكون، بحيث ينتج منه مجال مغناطيسي حثي يقاوم التغير في التدفق المغناطيسي المسبب له.

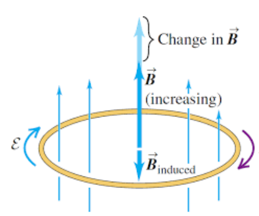
*إذا زاد التدفق المغناطيسي من خلال زيادة المجال المغناطيسي فحسب قانون لنز فإنه ينشأ تيار حثي بحيث ينتج مجال مغناطيسي حثي اتجاهه معاكس لاتجاه المجال المغناطيسي المسبب لتغير في التدفق المغناطيسي فيقاوم الزيادة فيه.

*إذا قل التدفق المغناطيسي من خلال إنقاص المجال المغناطيسي فحسب قانون لنز فإنه ينشأ تيار حثي بحيث ينتج مجال مغناطيسي حثي اتجاهه باتجاه المجال المغناطيسي المسبب لتغير في التدفق المغناطيسي فيقاوم النقصان فيه.

Example (5): In Figure there is a uniform magnetic field $\vec{B}$ through the coil. The magnitude of the field is increasing, so there is an induced emf. Use Lenz's law to determine the direction of the resulting induced current.



Solution



ملحوظات:

- ممكن في السؤال يطلب منك تحسب (angular speed) وذلك عن طريق:

$\phi = wt$

Where:

W: the angular speed.

$$\mathcal{E} = -N\frac{d\Phi_B}{dt} = -N\frac{d(B*A*COS(\phi))}{dt} = -N\frac{d(B*A*COS(wt))}{dt}$$

$$\boxed{\mathcal{E} = N*B*A*w*\sin(wt)}$$

- ممكن يقلك بالسؤال احسب (angular speed) عندما تكون (*max*):

At max: $\sin(wt) = 1$

$\mathcal{E} = N*B*A*w$

- انتبه على وحدة (angular speed) يجب ان تكون ($\frac{rad}{s}$) ممكن يعطيك الوحدة ($\frac{revolution}{s}$) فانت بتحولها ل ($\frac{rad}{s}$) عن طريق:

$1rev = 2\pi\ rad$

- إذا اعطاك بالسؤال طول (*rod*) وطلب منك (angular speed):

$$\mathcal{E} = \frac{B*w*L^2}{2}$$

Ex: A conducting rod (length = 80 cm) rotates at a constant angular rate of 15 revolutions per second about a pivot at one end. A uniform field (*B* = 60 mT) is directed perpendicularly to the plane of rotation. What is the magnitude of the emf induced between the ends of the rod?

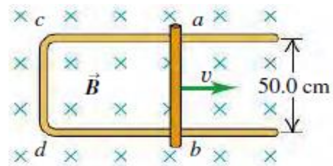
Solution: L = 80 cm *B* = 60 mT w = 15 ($\frac{revolution}{s}$)

$w = 15 * 2\pi = 30\pi\ (\frac{rad}{s})$

$\mathcal{E} = 0.5*B*w*L^2 = 0.5*60*10^{-3}*30\pi*(80*10^{-4})^2$

$$\boxed{\mathcal{E} = 1.81\ V}$$

Ex: The conducting rod ab as shown makes contact with metal rails ca and db. The apparatus is in a uniform magnetic field of 0.800 T, perpendicular to the plane of the figure.
(a) Find the magnitude of the emf induced in the rod when it is moving toward the right with a speed 7.50 m/s and what direction does the current flow in the rod.
(b) If the resistance of the circuit $abdc$ is 1.50Ω (assumed to be constant), find the force (magnitude and direction) required to keep the rod moving to the right with a constant speed of 7.50 m/s. You can ignore friction.



Solution:
a)
$\mathcal{E} = LVB = 7.50 * 0.800 * 0.5 = 3\text{v}$

$\vec{B}$is into the page. The flux increases as the bar moves to the right, so the magnetic field of the induced current is out of the page inside the circuit. To produce magnetic field in this direction the induced current must be counterclockwise, so from b to a in the rod.

b)
$I = \frac{\mathcal{E}}{R} = \frac{3}{1.5} = 2A$
$F = \text{ILB} = 2 * 0.5 * 0.8 = 0.8\text{N}$
$F\ is\ to\ left.$

Ex: if the magnetic flux is $\Phi_B = 5t^3 - 15t^2$ and the resistance $\text{R} = 5$. find I_{max} in this internal $t = 0 \rightarrow 2$:

$$\mathcal{E} = -\frac{d\Phi_B}{\text{dt}} = -15t^2 + 30t$$

$$I = \frac{\mathcal{E}}{R} = \frac{-15t^2 + 30t}{5} = -3t^2 + 6t$$

في السؤال طلب القيمة القصوى لتيار لذلك أشتق وساوي بالصفر:

-6t+6=0
$t = 1\text{s}$
$I = -3t^2 + 6t$
$I(1) = -3\,(1)^2 + 6 * 1 = 3$

أهم القوانين

Magnetic flux:

$\Phi_B = \vec{B} . \vec{A} = B * A * cos\phi$

Faraday's Law:

$\mathcal{E} = -\frac{d\Phi_B}{\mathrm{dt}}$

$I = \frac{\mathcal{E}}{R}$

Motion Induced Electromotive Force:

$\mathcal{E} = LVB$

Magnetic force:

$F = \mathrm{I}(\vec{L} \times \vec{B}) = ILBsin\emptyset$

$F = \mathrm{ILB} = \frac{\mathrm{L}^2\mathrm{B}^2 V}{R}$

$\mathrm{p}_{applied} = \mathrm{F} * \mathrm{V} = \frac{\mathrm{L}^2\mathrm{V}^2\mathrm{B}^2}{R}$

$\oint \vec{E} . \vec{dl} = -\frac{d\Phi_B}{\mathrm{dt}} = \mathcal{E}$

angular speed:

$\phi = wt$

$\mathcal{E} = N * B * A * w * \sin{(wt)}$

At max: $\sin(wt) = 1$

$\mathcal{E} = N * B * A * w$

1rev = 2π rad

❖ إذا اعطاك بالسؤال طول (rod) وطلب منك (angular speed):

$$\mathcal{E} = \frac{B * w * \mathrm{L}^2}{2}$$

Problems

Book & more

Q1) A single loop of wire with an area of 0.09 m^2 is in a uniform magnetic field that has an initial value of 3.80 T, is perpendicular to the plane of the loop, and is decreasing at a constant rate of 0.190 T/s. If the loop has a resistance of 0.6Ω, find the current induced in the loop.

$$\mathcal{E} = -\frac{d\Phi_B}{\mathrm{dt}} = -\frac{d\mathrm{B}}{\mathrm{dt}} * \mathrm{A} * \cos\phi = -(-0.19) * 0.09 = 0.0171\mathrm{v}$$
$$I = \frac{0.0171}{0.6} = 0.0285\ A$$

Q2) A coil 4.00 cm in radius, containing 500 turns, is placed in a uniform magnetic field that varies with time according to B = (0.0120) t + 13.00 * 10^{-5}) t^4. The coil is connected to a 600Ω resistor, and its plane is perpendicular to the magnetic field. You can ignore the resistance of the coil. What is the current in the resistor at time t = 5 s?

$N=500 \quad A=\pi * 0.04^2 \quad \phi = 0 \quad R=600$
$$\mathcal{E} = -\frac{d\Phi_B}{\mathrm{dt}} = -NA * \frac{d\mathrm{B}}{\mathrm{dt}} = 0.0302 + 3.02 * 10^{-4} * \mathrm{t}^3$$
At t =5:
$$I(t) = \frac{\mathcal{E}}{R} = \frac{0.0302 + 3.02 * 10^{-4} * \mathrm{t}^3}{600}$$
$$I(5) = \frac{0.0680}{600} = 1.13 * 10^{-4} A$$

Q3) The armature of a small generator consists of a flat, square coil with 120 turns and sides with a length of 1.60 cm. The coil rotates in a magnetic field of 0.0750 T. What is the angular speed of the coil if the maximum emf produced is 24.0 mV?

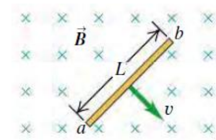
At max: $\sin(wt) = 1$
$\mathcal{E} = N * B * A * w$

$w = 10.4$

Q4) A rectangular loop of wire with dimensions 1.50 cm by 8.00 cm and resistance R = 0.600 Ω is being pulled to the right out of a region of uniform magnetic field. The magnetic field has magnitude B = 2.40 T and is directed into the plane. At the instant when the speed of the loop is 3.00 m/s and it is still partially in the field region, what force (magnitude and direction) does the magnetic field exert on the loop?

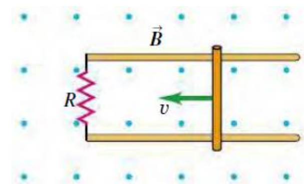
$$F = \mathrm{ILB} * \sin\theta = \frac{\mathrm{L}^2\mathrm{B}^2 V}{R} * \sin\theta = \frac{0.015^2 * 2.4^2 * 3}{0.6}\sin 90°$$
$$F = 6.48\mathrm{mN}$$

Q5) A conducting rod of length L = 30.0 cm moves in a magnetic field $\vec{B}$ of magnitude 0.450 T directed into the plane of the figure. The rod moves with speed v = 5.00 m/s in the direction shown. When the charges in the rod are in equilibrium, what are the magnitude and direction of the electric field within the rod.



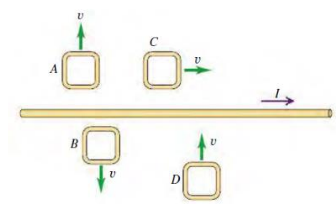
$$\mathcal{E} = LVB = 0.3 * 0.45 * 5 = 0.675v$$
$$E = \frac{V}{L} = \frac{0.675}{0.3} = 2.25$$

Q6) Consider the circuit shown in Figure, but with the bar moving to the right with speed v. the bar has length 0.360 m, R = 45.0 Ω, and B = 0.650 T. At an instant when the 45.0Ω resistor is dissipating electrical energy at a rate of 0.840 J/s, what is the speed of the bar?



$$P = I^2R \rightarrow 0.840 = I^2 * 45$$
$$I = 0.1366A$$
$$I = \frac{BVL}{R} \rightarrow V = \frac{IR}{BL} = 26.3\frac{m}{s}$$

Q7)The current I in a long, straight wire is constant and is directed toward the right. Conducting loops (A, B, C, and D) are moving, in the directions shown, near the wire. For each loop, is the direction of the induced current clockwise or counterclockwise, or is the induced current zero?



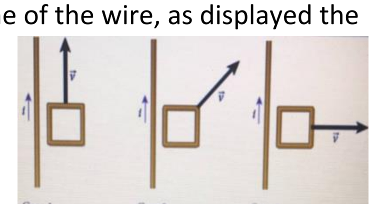
الملف (A): يبتعد عن السلك لذلك سوف يقل التدفق المغناطيسي في الملف لذلك يجب مقاومة النقصان والمجال المغناطيسي الأصل اتجاهه خارج الصفحة فينتج تيار حثي يولد مجال مغناطيسي باتجاه المجال المغناطيسي الأصلي خارج الصفحة. إذا اتجاه التيار الحثي عكس عقارب الساعة.

B: the flux through the loop is decreasing with the magnetic field into the page, so the induced current is clockwise.

C: the flux through the loop is constant, so there is no induced current.

D: the flux through the loop is increasing with the magnetic field into the page, so the induced current is counterclockwise.

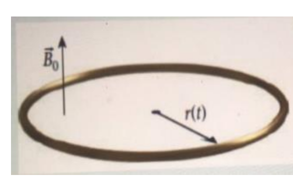
Q8) While the straight wire is fixed, the loop is moving in the same plane of the wire, as displayed the case(s) in which a current will be induced in the loop is (are):



case2 and case 3

Q9)As shown, a circular conducting loop (with 4 turns and of resistance R=8.8Ω) is placed in a uniform magnetic field directed normal to the plane of the loop, of magnetic $\vec{B_\circ} = 1.4\ T$. The radius of the loop varies with time according to the formula $r(t) = a + bt$. The magnitude of the current (in mA) induced in the loop at t = 11s is :(take a= 0.14 m, and b = 0.02ms^{-1})

Answer: 28.8



تمارين مهمة جدا:

1-A circular loop of wire (radius = 6.0 cm, resistance = 40 $m\Omega$) is placed in a uniform magnetic field that makes an angle of 30° with the plane of the loop. The magnitude of the field changes with time according to $B = 30 \sin(20t)$ mT, where t is measured in s. Determine the magnitude of the current induced in the loop at $t = \pi/20\ s$.

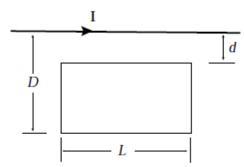
a. zero **b.** 0.17 A **c.** 8.5 mA **d.** 6.8 mA **e.** 0.34 mA

2-A 40-turn circular coil (radius = 4.0 cm, total resistance = 0.20 Ω) is placed in a uniform magnetic field directed perpendicular to the plane of the coil. The magnitude of the magnetic field varies with time as given by $B = 50 \sin(10\pi t)$ mT where t is measured in s. What is the magnitude of the induced current in the coil at 0.10 s?

a. 50 mA **b.** 0.80 A **c.** 0.32 A **d.** zero **e.** 1.6 A

3-A loop of wire (resistance = 2.0 mΩ) is positioned as shown with respect to a long wire which carries a current. If d = 1.0 cm, D = 6.0 cm, and L = 1.5 m, what current is induced in the loop at an instant when the current in the wire is increasing at a rate of 100 A/s?

a. 34 mA **b.** 30 mA **c.** 27 mA **d.** 38 mA **e.** 0.50 mA

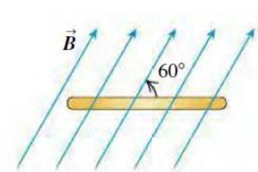


4- A single loop of wire with an area of 0.0900 m^2 is in a uniform magnetic field that has an initial value of 3.80 T, is perpendicular to the plane of the loop, and is decreasing at a constant rate of 0.190 T/s.What emf is induced in this loop?

Answer: ……………………

5-A flat, circular, steel loop of radius 75 cm is at rest in a uniform magnetic field, as shown in an edge-on view in figure. The field is changing with time, according to $B(t) = (1.4T)e^{-(0.057s^{-1})t}$.Find the emf induced in the loop as a function of time.

Answer: ……………………



6-A coil is wrapped with 300 turns of wire on the perimeter of a square frame (side length = 20 cm). Each turn has the same area as the frame, and the total resistance of the coil is 1.5 Ω. A uniform magnetic field perpendicular to the plane of the coil, changes in magnitude at a constant rate from 0.50 T to 0.90 T in 2.0 s. What is the magnitude of the induced emf in the coil while the field is changing?

a. 2.4 V **b.** 1.6 V **c.** 3.2 V **d.** 4.0 V **e.** 8.4 V

7-A 5-turn square loop (10 cm along a side, resistance = 4.0 Ω) is placed in a magnetic field that makes an angle of 30° with the plane of the loop. The magnitude of this field varies with time according to B = $0.50t^2$, where t is measured in s and B in T. What is the induced current in the coil at t = 4.0 s?

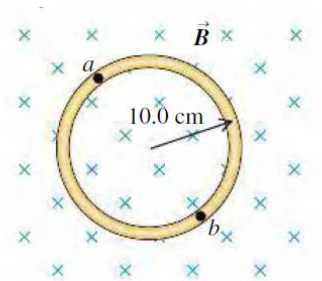
a. 25 mA **b.** 5.0 mA **c.** 13 mA **d.** 43 mA **e.** 50 mA

8-A 50-turn circular coil (radius = 15 cm) with a total resistance of 4.0 Ω is placed in a uniform magnetic field directed perpendicularly to the plane of the coil. The magnitude of this field varies with time according to $B = A \sin(\alpha t)$, where A = 80 μT and α = 50π rad/s. What is the magnitude of the current induced in the coil at t = 20 ms?

a. 22 mA **b.** 18 mA **c.** 14 mA **d.** 11 mA **e.** zero

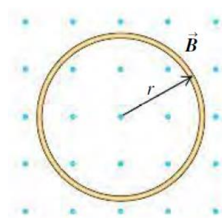
9-A circular loop of wire is in a region of spatially uniform magnetic field, as shown, the magnetic field is directed into the plane of the figure. Determine the direction (clockwise or counterclockwise) of the induced current in the loop when B is increasing?

Answer: ……………………



10-A circular loop of wire with radius r = 0.0480 m and resistance R = 0.160 Ω is in a region of spatially uniform magnetic field, as shown in figure. The magnetic field is directed out of the plane of the figure. The magnetic field has an initial value of 8.00 T and is decreasing at a rate of dB/dt = -0.680 T/s. Is the induced current in the loop clockwise or counterclockwise?

Answer: ……………………



11-A long solenoid (n = 1500 turns/m) has a cross-sectional area of 0.40 m2 and a current given by I = $(4.0 + 3.0t^2)$ A, where t is in seconds. A flat circular coil (N = 300 turns) with a cross sectional area of 0.15 m^2 is inside and coaxial with the solenoid. What is the magnitude of the emf induced in the coil at t = 2.0 s?

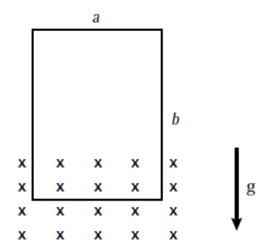
a. 2.7 V **b.** 1.0 V **c.** 6.8 V **d.** 0.68 V **e.** 1.4 V

12-A rectangular loop (area = 0.20 m2) is placed in a region where the magnetic field is uniform and perpendicular to the plane of the loop. The magnitude of the magnetic field varies according to $B = B_\circ e^t/\tau$, where $B_\circ = 0.40\ T$ and $\tau = 4.0\ s$. What is the magnitude of the emf induced in the loop at t = 2.0 s?

a. 29 mV **b.** 130 mV **c.** 37 mV **d.** 25 mV **e.** 33 mV

13-A conducting rectangular loop of mass M, resistance R, and dimensions $a \times b$ is allowed to fall from rest through a uniform magnetic field which is perpendicular to the plane of the loop. The loop accelerates until it reaches a terminal speed (before the upper end enters the magnetic field). If a = 2.0 m, B = 6.0 T, $R = 40\ \Omega$, and M = 0.60 kg, what is the terminal speed?

a. 1.6 m/s **b.** 20 m/s **c.** 2.2 m/s **d.** 26 m/s **e.** 5.3 m/s



14-A long, thin solenoid has 900 turns per meter and radius 2.50 cm. The current in the solenoid is increasing at a uniform rate of 36.0 A/s. What is the magnitude of the induced electric field at a point near the center of the solenoid and 0.500 cm from the axis of the solenoid?

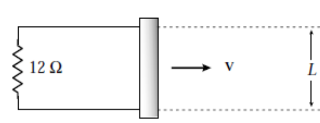
Answer: …………………….

15-A long, thin solenoid has 400 turns per meter and radius 1.10 cm. The current in the solenoid is increasing at a uniform rate di/dt. The induced electric field at a point near the center of the solenoid and 3.50 cm from its axis is $8.00 * 10^{-6}\ V/m$. Calculate di/dt.

Answer: …………………….

16-A rod (length = 10 cm) moves on two horizontal frictionless conducting rails, as shown. The magnetic field in the region is directed perpendicularly to the plane of the rails and is uniform and constant. If a constant force of 0.60 N moves the bar at a constant velocity of 2.0 m/s, what is the current through the $12-\Omega$ load resistor?

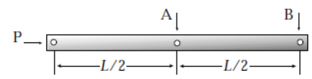
a. 0.32 A **b.** 0.34 A **c.** 0.37 A **d.** 0.39 A **e.** 0.43 A



17-A conducting rod (length = 2.0 m) spins at a constant rate of 2.0 revolutions per second about an axis that is perpendicular to the rod and through its center. A uniform magnetic field (magnitude = 8.0 mT) is directed perpendicularly to the plane of rotation. What is the magnitude of the potential difference between the center of the rod and either of its ends?

a. 16 mV **b.** 50 mV **c.** 8.0 mV **d.** 0.10 mV **e.** 100 mV

18-A conducting bar of length *L* rotates with a constant angular speed of +2.0 rad/s about a pivot P at one end, as shown. A uniform magnetic field (magnitude = 0.20 T) is directed into the paper. If *L* = 0.40 m, what is the potential difference, *VA* – *VB*?



a. -16 mV **b.** –24 mV **c.** +16 mV **d.** +24 mV **e.** +32 mV

19-At what frequency should a 200-turn, flat coil of cross-sectional area of 300 cm2 be rotated in a uniform 30-mT magnetic field to have a maximum value of the induced emf equal to 8.0 V?

a. 7.5 Hz **b.** 16 Hz **c.** 8.0 Hz **d.** 8.4 Hz **e.** 7.1 Hz

20-A current may be induced in a coil by

a. moving one end of a bar magnet through the coil.
b. moving the coil toward one end of the bar magnet.
c. holding the coil near a second coil while the electric current in the second coil is increasing.
d. all the above.
e. none of the above

1.	**b.** 0.17 A	11.	**b.** 1.0 V
2.	**e.** 1.6 A	12.	**e.** 33 mV
3.	**c.** 27 mA	13.	**a.** 1.6 m/s
4.	$\lvert\varepsilon\rvert = 0.0171\ V$	14.	$E = 1.02 * 10^{-4}\ V/m$
5.	$\lvert\varepsilon_{ind}\rvert = (0.122\ V)e^{-(0.057\ s^{-1})t}$	15.	$di/dt = 9.21\ A/s$
6.	**b.** 1.6 V	16.	**a.** 0.32 A
7.	**a.** 25 mA	17.	**b.** 50 mV
8.	**d.** 11 mA	18.	**d.** +24 mV
9.	counterclockwise	19.	**e.** 7.1 Hz
10.	counterclockwise	20.	**d.** all the above.