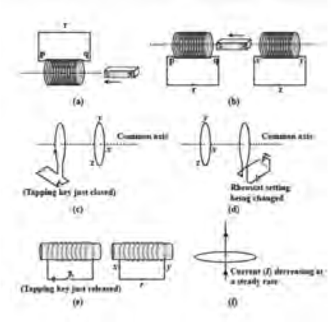
#420328

Topic: Faraday's and Lenz's Law



Predict the direction of induced current in the situations described by the following Figs. (a) to (f).

Solution

The direction of the induced current in a closed loop is given by Lenz’s law. The given pairs of figures show the direction of the induced current when the North pole of a bar magnet is moved towards and away from a closed loop respectively.

Using Lenz’s rule, the direction of the induced current in the given situations can be predicted as follows:

(a) The direction of the induced current is along **qrpq**.

(b) The direction of the induced current is along **prqp**.

(c) The direction of the induced current is along **yzxy**.

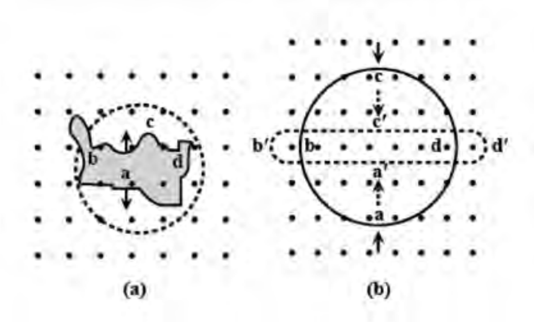
(d) The direction of the induced current is along **zyxz**.

(e) The direction of the induced current is along **xryx**.

(f) No current is induced since the field lines are lying in the plane of the closed loop.

#420346

Topic: Faraday's and Lenz's Law



Use Lenz's law to determine the direction of induced current in the situations described by Fig.

(a) A wire of irregular shape turning into a circular shape;

(b) A circular loop being deformed into a narrow straight wire.

Solution

According to the Lenz's law, the current induced will oppose the change in flux through the loop.

(a) Since the area of loop is increasing with time, the flux through it will increase and hence the current induced will be such that its magnetic field produced is in the opposite direction.

Hence according to right hand rule, the current will be in clockwise direction

(b) Since the area of loop is decreasing with time, the flux through it will decrease and hence the current induced will be such that its magnetic field produced is in the same direction to maintain the flux right hand rule, Direction of current, - adcb

#420350

Topic: Motional EMF

A long solenoid with 15 turns per cm has a small loop of area $2.0cm^2$ placed inside the solenoid normal to its axis. If the current carried by the solenoid changes steadily from 2.0 A to 4.0 A in 0.1 s, what is the induced emf in the loop while the current is changing?

Solution

Number of turns on the solenoid = 15 turns/cm = 1500 turns/m

Number of turns per unit length, n = 1500 turns

The solenoid has a small loop of area, A = $2.0cm^2$

Current carried by the solenoid changes from 2 A to 4 A.

Change in current in the solenoid, $di = 4 - 2 = 2A$

Change in time, $dt = 0.1s$

Induced emf in the solenoid is given by Faraday's law as:

$e = \frac{d\phi}{dt}$ ...(i)

Where,

$\phi =$ Induced flux through the small loop

$= BA$ ... (ii)

$B =$ Magnetic field

$= \mu_0 ni$ ...(iii)

$\mu 0 =$ Permeability of free space

$= 4\pi \times 10^{-7} H/m$

Hence, equation (i) reduces to:

$e = \frac{d}{dt}(BA)$

$= A\mu_0 n \times \left(\frac{di}{dt}\right)$

$= 2 \times 10^{-4} \times 4\pi \times 10^{-7} \times 1500 \times \frac{2}{0.1}$

$= 7.54 \times 10^{-6} V$

Hence, the induced voltage in the loop is $7.54 \times 10^{-6} V$.

#420352

Topic: Motional EMF

A rectangular wire loop of sides 8 cm and 2 cm with a small cut is moving out of a region of uniform magnetic field of magnitude 0.3 T directed normal to the loop. What is the emf developed across the cut if the velocity of the loop is 1 cm s^{-1} in a direction normal to the (a) longer side, (b) shorter side of the loop? For how long does the induced voltage last in each case?

Solution

Length of the rectangular wire, $l = 8cm = 0.08m$

Width of the rectangular wire, $b = 2cm = 0.02m$

Hence, area of the rectangular loop,

$A = lb$

$= 0.08 \times 0.02$

$= 16 \times 10^{-4} m^2$

Magnetic field strength, $B = 0.3T$

Velocity of the loop, $v = 1cm/s = 0.01m/s$

(a)

Emf developed in the loop is given as:

$e = Blv$

$= 0.3 \times 0.08 \times 0.01 = 2.4 \times 10^{-4} V$

Time taken to travel along the width, $t = \frac{Distance\,travelled}{Velocity} = \frac{b}{v}$

$= \frac{0.02}{0.01} = 2s$

Hence, the induced voltage is $2.4 \times 10^{-4} V$ which lasts for 2 s.

(b)

Emf developed, $e = Bbv$

$= 0.3 \times 0.02 \times 0.01 = 0.6 \times 10^{-4} V$

Time taken to travel along the length, $t = \frac{Distance\,traveled}{Velocity} = \frac{l}{v}$

$= \frac{0.08}{0.01} = 8s$

Hence, the induced voltage is $0.6 \times 10^{-4} V$ which lasts for 8 s.

#420356

Topic: Motional EMF

A 1.0 m long metallic rod is rotated with an angular frequency of 400 rad s^{-1} about an axis normal to the rod passing through its one end. The other end of the rod is in contac with a circular metallic ring. A constant and uniform magnetic field of 0.5 T parallel to the axis exists everywhere. Calculate the emf developed between the centre and the ring

Solution

The emf is given by

$e = \frac{Bl^2\omega}{2} = \frac{0.5 \times 1^2 \times 400}{2} = 100V$

#420357

Topic: Motional EMF

A circular coil of radius 8.0 cm and 20 turns is rotated about its vertical diameter with an angular speed of $50\ rads^{-1}$ in a uniform horizontal magnetic field of magnitude $3.0 \times 10^{-2} T$. Obtain the maximum and average emf induced in the coil. If the coil forms a closed loop of resistance 10 , calculate the maximum value of current in the coil. Calculate the average power loss due to Joule heating. Where does this power come from?

Solution

Maximum induced emf $e = N\omega AB$;

$N = no.\ of\ turns, \omega = angular\ speed, A = Area\ of\ coil, B = Magnetic\ field$

$\Rightarrow e = 0.603V$

Over a full cycle, the average emf induced in the coil is zero.

Maximum current, $I = e/R = 0.0603$

Average power loss due to joule heating is $P = \dfrac{eI}{2} = 0.018\ W$

#420405

Topic: Motional EMF

A horizontal straight wire 10 m long extending from east to west is falling with a speed of $5.0ms^{-1}$, at right angles to the horizontal component of the earth's magnetic field 0.3 $\times 10^{-4}WBm^{-2}$.

(a) What is the instantaneous value of the emf induced in the wire?

(b) What is the direction of the emf?

(c) Which end of the wire is at the higher electrical potential?

Solution

(a)

$l = 10\ cm, v = 5.0\ m/s, B = 0.3 \times 10^{-4}Wbm^{-2}$

Induce EMF is $e = Blv = 1.5 \times 10^{-3}V$

(b)

Using Fleming's right hand rule, it can be inferred that the direction of the induced emf is from West to East.

(c)

The eastern end of the wire is at a higher potential.

#420421

Topic: Inductance

Current in a circuit falls from 5.0 A to 0.0 A in 0.1 s. If an average emf of 200 V induced, find an estimate of the self-inductance of the circuit.

Solution

The emf is related to inductance by the equation,

$e = L\dfrac{di}{dt}$.

Now, $L = \dfrac{e}{\frac{di}{dt}} = \dfrac{200}{\frac{5}{0.1}} = 4H$.

#420422

Topic: Inductance

A pair of adjacent coils has a mutual inductance of 1.5 H. If the current in one coil changes from 0 to 20 A in 0.5 s, what is the change of flux linkage with the other coil?

Solution

We know that

$e = \dfrac{d\phi}{dt} = M\dfrac{di}{dt}$

Therefore,

$d\phi = Mdi = 1.5 \times (20 - 0) = 30Wb$

#420427

Topic: Motional EMF

A jet plane is travelling towards west at a speed of 1800 km/h. What is the voltage difference developed between the ends of the wing having a span of 25 m, if the Earths magnetic field at the location has a magnitude of 5 $\times 10^{-4}$ T and the dip angle is 30^o.

Solution

Vertical component of B,

$B\sin\delta = 5\times10^{-4}\times\sin(30) = 2.5\times10^{-4}T$

EMF, $E = Blv$

$E = 2.5\times10^{-4}\times 25\times 1800\times\dfrac{5}{18} = 3.125V$

#420434

Topic: Motional EMF

Suppose the loop in Exercise is stationary but the current feeding the electromagnet that produces the magnetic field is gradually reduced so that the field decreases from its initial value of 0.3 T at the rate of 0.02 T s^{-1}. If the cut is joined and the loop has a resistance of 1.6 ohm , how much power is dissipated by the loop as heat? What is the sourc of this power?

Exercise :

[A rectangular wire loop of sides 8 cm and 2 cm with a small cut is moving out of a region of uniform magnetic field of magnitude 0.3 T directed normal to the loop. What is the emf developed across the cut if the velocity of the loop is 1 cm s^{-1} in a direction normal to the (a) longer side, (b) shorter side of the loop? For how long does the induced voltage last in each case?]

Solution

$A = 8\times2 = 16\ cm^2$

emf, $e = \dfrac{d(A\times B)}{dt} = 0.32\times10^{-4}V$

Induced current, $i = e/R = 2\times10^{-5}A$

Power, $P = i^2R = 6.4\times10^{-10}\ W$

#420461

Topic: Faraday's and Lenz's Law

A square loop of side 12 cm with its sides parallel to X and Y axes is moved with a velocity of $8\ cm\ s^{-1}$ in the positive x-direction in an environment containing a magnetic field in the positive z-direction. The field is neither uniform in space nor constant in time. It has a gradient of $10^{-3}\ T\ cm^{-1}$ along the negative x-direction (that is it increases by $10^{-3}\ T\ cm^{-1}$ as one moves in the negative x-direction), and it is decreasing in time at the rate of $10^{-3}\ T\ s^{-1}$. Determine the direction and magnitude of the induced current ir the loop if its resistance is 4.50 mΩ.

Solution

$\dfrac{dB}{dx} = 10^{-1}Tm^{-1}$

$\dfrac{dB}{dt} = 10^{-3}Ts^{-1}$

$\phi = flux;\ A = area$

also, $\dfrac{d\phi}{dt} = A\times\dfrac{dB}{dx}\times V = 11.52\times10^{-5}$

Rate of change of flux to explicit time variation is $\dfrac{d\phi'}{dt} = A\times\dfrac{dB}{dt} = 1.44\times10^{-5}$

$e = 11.52\times10^{-5} + 1.44\times10^{-5}$

$i = e/R = 2.8\times10^{-2}A$

#420467

Topic: Motional EMF

It is desired to measure the magnitude of field between the poles of a powerful loud speaker magnet. A small flat search coil of area $2\ cm^2$ with 25 closely wound turns, is positioned normal to the field direction, and then quickly snatched out of the field region. Equivalently, one can give it a quick 90° turn to bring its plane parallel to the field direction). The total charge flown in the coil (measured by a ballistic galvanometer connected to coil) is 7.5 mC. The combined resistance of the coil and the galvanometer is 0.! Ω. Estimate the field strength of magnet.

Solution

$$Q = \int_{t_i}^{t_f} Idt$$
$$= \frac{1}{R}\int_{t_i}^{t_f} \varepsilon dt$$
$$= -\frac{N}{R}\int_{\Phi_i}^{\Phi_f} d\Phi$$
$$= \frac{N}{R}(\Phi_i - \Phi_f)$$
$N = 25, R = 0.50\Omega, Q = 7.5 \times 10^{-3}\,C$

$\Phi_f = 0, \quad A = 2.0 \times 10^{-4}\,m^2$

$\implies \Phi_i = 1.5 \times 10^{-4}\,Wb$

$B = \Phi_i\,/\,A = 0.75\,T$

#420474

Topic: Motional EMF

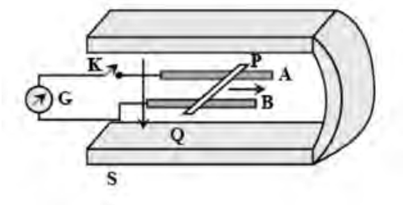


Figure shows a metal rod PQ resting on the smooth rails AB and positioned between the poles of a permanent magnet. The rails,the rod, and the magnetic field are in three mutual perpendicular directions. A galvanometer G connects the rails through a switch K. Length of the rod = 15 cm, B = 0.50 T, resistance of the closed loop containing the roc 9.0 mΩ. Assume the field to be uniform.

(a) Suppose K is open and the rod is moved with a speed of $12\,cm\,s^{-1}$ in the direction shown. Give the polarity and magnitude of the induced emf.

(b) Is there an excess charge built up at the ends of the rods when K is open? What if K is closed?

(c) With K open and the rod moving uniformly, there is no net force on the electrons in the rod PQ even though they do experience magnetic force due to the motion of the rod Explain.

(d) What is the retarding force on the rod when K is closed?

(e) How much power is required (by an external agent) to keep the rod moving at the same speed $(= 12\,cm\,s^{-1})$ when K is closed? How much power is required when K is open?

(f) How much power is dissipated as heat in the closed circuit? What is the source of this power?

(g) What is the induced emf in the moving rod if the magnetic field is parallel to the rails instead of being perpendicular?

Solution

(a)

Induce EMF is $e = Blv = 9 \times 10^{-3} V$

The polarity of the induced emf is such that end P shows positive while end Q shows negative ends.

(b)

Yes; when key K is closed, excess charge is maintained by the continuous flow of current.

When key K is open, there is excess charge built up at both ends of the rods.

When key K is closed, excess charge is maintained by the continuous flow of current.

(c)

Magnetic force is cancelled by the electric force set-up due to the excess charge of opposite nature at both ends of the rod.

(d)

Retarding force exerted on the rod, $F = IBl$

$I = e/R = 9 \times 10^{-3}/9 \times 10^{-3} = 1A$

so, $F = 1 \times 0.5 \times 0.15 = 75 \times 10^{-3} N$

(e)

Retarding force, $F = BIl$

where, $I = e/R = 1A$

so, $F = 75 \times 10^{-3} N$

Also, Power $P = Fv = 75 \times 10^{-3} \times 0.12 = 9mW$

(f)

Power dissipated = $I^2 R = 9mW$

The source of this power external agent.

(g)

Zero. As, in this case, no emf is induced in the coil because the motion of the rod does not cut across the field lines.

#420492

Topic: Motional EMF

An air-cored solenoid with length 30 cm, area of cross-section $25\ cm^2$ and number of turns 500, carries a current of 2.5 A. The current is suddenly switched off in a brief time c $10^{-3}\ s$. How much is the average back emf induced across the ends of the open switch in the circuit? Ignore the variation in magnetic field near the ends of the solenoid.

Solution

$B = \frac{\mu_0 NI}{l}$

(Inside the solenoid away from the ends)

$\Phi = \frac{\mu_0 NI}{l} A$

Total flux linkage = $N\phi$

$= \frac{\mu_0 N^2 A}{l} I$

(Ignoring end variations in B)

$|\varepsilon| = \frac{d}{dt}(N\Phi)$

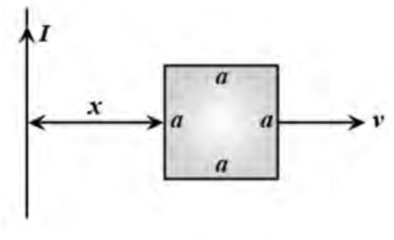
$|\varepsilon|_{av} = \frac{total\ change\ in\ flux}{total\ time}$

$|\varepsilon|_{av} = \frac{4\pi \times 10^{-7} \times 25 \times 10^{-4}}{0.3 \times 10^{-3}} \times (500)^2 \times 2.5$

$= 6.5\,V$

#420496

Topic: Inductance



(a) Obtain an expression for the mutual inductance between a long straight wire and a square loop of side a as shown in Fig.

(b) Now assume that the straight wire carries a current of 50 A and the loop is moved to the right with a constant velocity, v = 10 m/s. Calculate the induced emf in the loop at th instant when x = 0.2 m. Take a = 0.1 m and assume that the loop has a large resistance.

Solution

Take a small element dy in the loop at a distance y from the long straight wire.

Magnetic flux associated with element, dy is $d\phi = BdA$

Where, $dA = a \times dy$is Area of element dy

$B = \mu_o I/2\pi y$ is magnetic field at y.

I is current in the wire.

$\therefore d\phi = \mu_o Ia \times dy/2\pi y$

$\phi = (\mu_o Ia/2\pi)\int_x^{a+x} dy/y$

$\Rightarrow \phi = (\mu_o Ia/2\pi) ln(\frac{a+x}{x})$

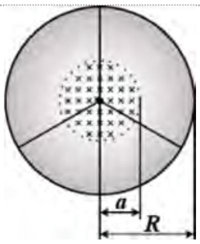
Mutual Inductance $M = \phi/I = (\mu_o a/2\pi) ln(\frac{a+x}{x})$

Emf induced in the loop, $e = Bav = (\mu_o I/2\pi x)av$

From the given values, $e = 5 \times 10^{-5}\ V$

#420499

Topic: Motional EMF



A line charge λ per unit length is lodged uniformly onto the rim of a wheel of mass M and radius R. The wheel has light non-conducting spokes and is free to rotate without friction about its axis as shown in above figure. A uniform magnetic field extends over a circular region within the rim. It is given by,

$B = -B_0\, k \quad (r \leq a;\ a < R)$ or $B = 0$ (otherwise).

What is the angular velocity of the wheel after the field is suddenly switched off?

Solution

Line charge per unit length, $\lambda = Q/2\pi r$

at distance r, the magnetic force is balanced by the centripetal force.

So, $BQv = Mv^2/r$

also the angular velocity, $\omega = v/R = B2\pi\lambda r^2/MR$

So for $r \leq a; a < R$ we get:

$\omega = -2B_o a^2 \lambda k/MR$

#464881
Topic: Faraday's and Lenz's Law

The phenomenon of electromagnetic induction is :

A the process of charging a body

B the process of generating magnetic field due to a current passing through a coil

C producing induced current in a coil due to relative motion between a magnet and the coil

D the process of rotating a coil of an electric motor

Solution

Electromagnetic induction is a phenomenon in which a changing magnetic field across a loop of wire results in the generation of an induced emf. When there is relative motior between a magnet and the coil, magnetic flux changes and hence an electromotive force is generated in the coil. This electromotive force generates induced current.

#464882
Topic: AC Generator

The device used for producing electric current is called a :

A generator.

B galvanometer.

C ammeter.

D motor.

Solution

Generator is an electromechanical device that converts mechanical energy to electrical energy. It uses the phenomenon of electromagnetic induction with the help of turbines. External mechanical energy is used to rotate the turbines which changes the magnetic flux through the coil. This results in the production of an emf and induced currents.

#464883
Topic: AC Generator

The essential difference between an AC generator and a DC generator is that:

A AC generator has an electromagnet while a DC generator has permanent magnet.

B DC generator will generate a higher voltage.

C AC generator will generate a higher voltage.

D AC generator has slip rings while DC generator has a commutator.

Solution

Slip rings are required during rotation while transmitting power in an AC generator. It greatly simplifies system operation and improves efficiency.

Commutator is used in a generator to periodically reverse the direction of current between rotor and external circuit. It hence helps in the conversion of AC to DC. It is used on in DC generators.

#464886

Topic: AC Generator

State whether following statements are True or False:

(a) An electric motor converts mechanical energy into electrical energy

(b) An electric generator works on principle of electromagnetic induction

(c) The field at the center of a long circular coil carrying current will be parallel straight lines

(d) A wire with a green insulation is usually the live wire of an electric supply

Solution

(a) False

An electric motor converts electrical energy into mechanical energy. As current carrying coil is placed in a magnetic field, it experiences a force due to which it starts rotating.

(b) True

An electric generator works on the principle of electromagnetic induction. When the coil is rotated by external mechanical forces in a magnetic field, the magnetic flux through the coil changes. This creates an induced emf in the coil and hence induced current flows.

(c) True

The field at the center of a long solenoid carrying current will be parallel straight lines. This can also be verified by Right hand thumb Rule.

(d) False

Live wire has red insulation cover, whereas earth wire has green insulation colour in the domestic circuits.

#464894

Topic: Faraday's and Lenz's Law

Two circular coils A and B are placed close to each other . If the current in the coil A is changed, some current be induced in the coil B. Give reason.

Solution

When two circular coils A and B are placed close to each other, and the current in the coil A is changed then some current will be induced in the coil B and the magnetic field associated with it also changes. Thus the magnetic field around coil B also changes. This change in the magnetic field lines around coil B induces an electric current in it. This process is known as electromagnetic induction.

#464896

Topic: AC Generator

Explain the underlying principle and working of electric generator by drawing a labelled diagram. What is the function of brushes?

Solution

Mechanical energy is converted to electrical energy in an electric generator. The working principle of an electric motor is Fleming's right hand rule.

Electric current is induced in an insulated copper coil when it is forced to rotate in a magnetic field. Circuit diagram of a simple AC generator is shown in the figure. If axle X is rotated clockwise, then the length PQ moves upwards and the length RS moves downwards.

Since the lengths PQ and RS are moving in a magnetic field, a current will be induced due to electromagnetic induction. Length PQ is moving upwards and the magnetic field acts from left to right. According to Fleming's right hand rule, the direction of induced current will be from P to Q. Similarly, the direction of induced current in the length RS will be from R to S. The direction of current in the coil is PQRS. Hence, the galvanometer shows the deflection in a particular direction. After half a rotation, length PQ starts moving down whereas length RS starts moving upward. The direction of the induced current in the coil gets reversed as SRQP. As the direction of current gets reversed after each hal rotation, the produced current is known as alternating current (AC). To get a unidirectional current, instead of two slip rings, two split rings are used, as shown in attached figure

In this arrangement, brush A always remains in contact with the length of the coil that is moving up whereas brush B always remain in contact with the length that is moving down. The split rings C and D act as commutator. The direction of current induced in the coil will be PQRS for the first half and SRQP for second half of rotation. Thus a unidirectional current is produced from generator called as DC generator.