001 10.0 points
A conductor consists of an infinite number of adjacent wires, each infinitely long and carrying a current \( I \) (whose direction is out-of-the-page), thus forming a conducting plane.

A conductor consists of an infinite number of adjacent wires, each infinitely long and carrying a current \( I \) (whose direction is out-of-the-page), thus forming a conducting plane.

If there are \( n \) wires per unit length, what is the magnitude of \( \vec{B} \)?

1. \( B = \frac{\mu_0 I}{2} \)
2. \( B = 4 \mu_0 I \)
3. \( B = 2 \mu_0 n I \)
4. \( B = 4 \mu_0 n I \)
5. \( B = \mu_0 I \)
6. \( B = 2 \mu_0 I \)
7. \( B = \frac{\mu_0 n I}{4} \)
8. \( B = \frac{\mu_0 I}{4} \)
9. \( B = \frac{\mu_0 n I}{2} \) correct
10. \( B = \mu_0 n I \)

Explanation:

By symmetry the magnetic fields are equal and opposite through point \( A \) and \( C \) and horizontally oriented. Following the dashed curve in a counter-clockwise direction, we calculate \( \oint \vec{B} \cdot d\vec{s} \), which by Ampere’s law is proportional to the current through the dashed loop coming out of the plane of the paper. In this problem this is a positive current. Hence \( \vec{B} \) along the horizontal legs points in the direction in which we follow the dashed curve. Ampere’s Law is

\[
\int \vec{B} \cdot d\vec{s} = \mu_0 I.
\]

To evaluate this line integral, we use the rectangular path shown in the figure. The rectangle has dimensions \( l \) and \( w \). The net current through the loop is \( n II \). Note that since there is no component of \( \vec{B} \) in the direction of \( w \), we are only interested in the contributions along sides \( l \)

\[
\oint \vec{B} \cdot d\vec{s} = 2Bl = \mu_0 nll
\]

\[
B = \frac{\mu_0 n I}{2}.
\]

002 10.0 points
A superconducting solenoid has 5810 turns/m and carries a current of 2000 A. What is the magnetic field generated inside the solenoid? The permeability of free space is \( 1.25664 \times 10^{-6} \text{ T} \cdot \text{m/A} \).

Correct answer: 14.6021 T.

Explanation:

Let:
\[
\begin{align*}
n & = 5810 \text{ turns/m}, \\
\mu_0 & = 1.25664 \times 10^{-6} \text{ T} \cdot \text{m/A}, \quad \text{and} \\
I & = 2000 \text{ A}.
\end{align*}
\]
The magnetic field generated inside the solenoid is
\[ B = \mu_0 n I \]
\[ = (1.25664 \times 10^{-6} \text{ T} \cdot \text{m}/\text{A}) \times (5810 \text{ turns/m}) (2000 \text{ A}) \]
\[ = 14.6021 \text{ T}. \]

keywords:

003 (part 1 of 2) 10.0 points
A capacitor of capacitance \( C \) has a charge \( Q \) at \( t = 0 \). At that time, a resistor of resistance \( R \) is connected to the plates of the charged capacitor. Find the magnitude of the displacement current between the plates of the capacitor as a function of time.

1. \( \frac{Q}{RC} e^{-t/Q} \)
2. \( \frac{RC}{Q} e^{t/(RC)} \)
3. \( \frac{Q}{RC} e^{-t/(RC)} \) correct
4. \( \frac{Q}{RC} e^{t/(RC)} \)
5. \( \frac{RC}{Q} e^{-t/(RC)} \)

Explanation:

Basic Concept
RC circuits. Displacement Current.
The displacement current is defined to be
\[ I_d = \epsilon_0 \frac{d \Phi_E}{dt}. \]
The electric field inside a capacitor is essentially uniform and \( E = \frac{q}{\epsilon_0 A} \). Since the charge on a capacitor in a discharging \( RC \) circuit is given by \( q(t) = Q e^{-t/RC} \), the displacement current is found by
\[ I_d = \epsilon_0 \frac{d \Phi_E}{dt} = \epsilon_0 \frac{d}{dt} \left( \frac{q}{\epsilon_0 A} A \right) = \frac{dq}{dt} = \frac{Q}{RC} e^{-t/(RC)}. \]

Note that the displacement current equals the actual current in the wires to the capacitor. Thus, the Ampere-Maxwell law tells us that \( \vec{B} \) will be the same regardless of which current we evaluate.

004 (part 2 of 2) 10.0 points
Given \( C = 3 \mu \text{F}, Q = 37 \mu \text{C}, R = 384 \text{kΩ}, \) and \( \epsilon_0 = 8.85419 \times 10^{-12} \text{ C}^2/\text{N} \cdot \text{m}^2 \), at what rate is the electric flux between the plates changing at time \( t = 0.19 \text{s} \)? Correct answer: \(-3.0759 \times 10^6 \text{ Vm/s}\).

Explanation:

Let : \( \epsilon_0 = 8.85419 \times 10^{-12} \text{ C}^2/\text{N} \cdot \text{m}^2 \), \( t = 0.19 \text{s} \), \( C = 3 \mu \text{F} \), \( Q = 37 \mu \text{C} = 3.7 \times 10^{-5} \text{ C} \), and \( R = 384 \text{kΩ} = 3.84 \times 10^5 \Omega \).

From the discussion in the previous part, we know that
\[ \frac{d \Phi_E}{dt} = \frac{I_d}{\epsilon_0} = -\frac{Q}{\epsilon_0 RC} e^{-t/(RC)} = -\frac{3.7 \times 10^{-5} \text{ C}}{\epsilon_0 (3.84 \times 10^5 \Omega)(3 \times 10^{-6} \text{ F})} \times e^{-t/(RC)} = -3.0759 \times 10^6 \text{ Vm/s}. \]

005 10.0 points
Given: A coil is suspended around an axis which is co-linear with the axis of a bar magnet. The coil is connected to a resistor with ends labeled “a” and “b”. The bar magnet moves from right to left with North and South poles labeled in the figure.

Use Lenz’s law to answer the following question concerning the direction of induced currents and magnetic fields.
The potential $V_a - V_b$ during this motion is

1. negative. **correct**

2. zero.

3. positive.

**Explanation:**

Note: The induced magnetic field depends on whether the flux is increasing or decreasing.

The magnetic flux through the coil is from right to left. When the magnet moves from right to left, the magnetic flux through the coils increases.

The induced current in the coil must produce an induced magnetic field from left to right ($B_{\text{induced}} \rightarrow$) to resist any change of magnetic flux in the coil (Lenz’s Law).

The helical coil when viewed from the bar magnet winds around the solenoid from terminal $b$ clockwise.

As the induced field is left to right ($B_{\text{induced}} \rightarrow$), the induced current must flow counter-clockwise and therefore it goes from “$b$” through $R$ to “$a$” (←). Consequently, the potential $V_{ba} = V_a - V_b$ is negative.

Note: There are eight different presentations of this problem and this is the eighth.

---

**006** 10.0 points

A coil is wrapped with 184 turns of wire on the perimeter of a square frame of sides 15.4 cm. Each turn has the same area, equal to that of the frame, and the total resistance of the coil is 2.38 $\Omega$. A uniform magnetic field is turned on perpendicular to the plane of the coil.

If the field changes linearly from 0 to 0.00162 Wb/m² in a time of 0.696 s, find the magnitude of the induced emf in the coil while the field is changing.

Correct answer: 0.010157 V.

**Solution:**

The magnetic flux through the loop at $t = 0$ is zero since $B = 0$. At $t = 0.696$ s, the magnetic flux through the loop is $\Phi_B = BA = 3.84199 \times 10^{-5}$ Wb. Therefore the magnitude of the induced emf is

$$\mathcal{E} = \frac{N \cdot \Delta \Phi_B}{\Delta t} = \frac{(184 \text{ turns}) \ [(3.84199 \times 10^{-5} \text{ Wb}) - 0]}{0.696 \text{ s}} = 0.010157 \text{ V}$$

$|\mathcal{E}| = 0.010157 \text{ V}$.

---

**007** 10.0 points

A solenoid with circular cross section produces a steadily increasing magnetic flux through its cross section. There is a octagonally shaped circuit surrounding the solenoid as shown. The increasing magnetic flux gives rise to a counterclockwise induced emf $\mathcal{E}$.

**Initial Case:** The circuit consists of two identical light bulbs of equal resistance $R$ connected in series, leading to a loop equation $\mathcal{E} - 2iR = 0$.

**Figure 1:**

The corresponding electrical power consumed by bulb $X$ and bulb $Y$ are $P_X$ and $P_Y$, respectively.

**Primed’ Case:** Now connect the points C and D with a wire CAD, as in figure 2.
Figure 2:

The corresponding electrical power consumed by bulb \( X \) and bulb \( Y \) are \( P'_X \) and \( P'_Y \), respectively.

What are the ratios \( \frac{P'_X}{P_X} \) and \( \frac{P'_Y}{P_Y} \), respectively?

1. \( \frac{P'_X}{P_X} = 1 \) and \( \frac{P'_Y}{P_Y} = 1 \)
2. \( \frac{P'_X}{P_X} = 4 \) and \( \frac{P'_Y}{P_Y} = \frac{1}{4} \)
3. \( \frac{P'_X}{P_X} = 4 \) and \( \frac{P'_Y}{P_Y} = \frac{1}{2} \)
4. \( \frac{P'_X}{P_X} = 2 \) and \( \frac{P'_Y}{P_Y} = \frac{1}{2} \)
5. \( \frac{P'_X}{P_X} = 0 \) and \( \frac{P'_Y}{P_Y} = 0 \)
6. \( \frac{P'_X}{P_X} = 2 \) and \( \frac{P'_Y}{P_Y} = 0 \)
7. \( \frac{P'_X}{P_X} = 2 \) and \( \frac{P'_Y}{P_Y} = \frac{1}{4} \)
8. \( \frac{P'_X}{P_X} = 0 \) and \( \frac{P'_Y}{P_Y} = \frac{1}{2} \)
9. \( \frac{P'_X}{P_X} = 4 \) and \( \frac{P'_Y}{P_Y} = 0 \) correct
10. \( \frac{P'_X}{P_X} = 0 \) and \( \frac{P'_Y}{P_Y} = \frac{1}{4} \)

Explanation:
Let \( \mathcal{E} \) and \( R \) be the induced emf and resistance of the light bulbs, respectively.

For the first case, since the two bulbs are in series, the equivalent resistance is simply \( R_{eq} = R + R = 2R \) and the current through the bulbs is

\[ i = \frac{\mathcal{E}}{2R}, \]

so the power consumed by bulb \( X \) is

\[ P_X = \left( \frac{\mathcal{E}}{2R} \right)^2 R = \frac{\mathcal{E}^2}{4R}. \]

For the second (primed) case, since bulb \( Y \) is shorted, the current through bulb \( X \) is now

\[ i' = \frac{\mathcal{E}}{R}, \]

and the power consumed by bulb \( X \) is

\[ P'_X = \left( \frac{\mathcal{E}}{R} \right)^2 R = \frac{\mathcal{E}^2}{R}. \]

Thus the ratio is

\[ \frac{P'_X}{P_X} = \frac{\mathcal{E}^2}{4R} \]

008 10.0 points
In the arrangement shown in the figure, the resistor is 7 \( \Omega \) and a 1 T magnetic field is directed into the paper. The separation between the rails is 8 m. Neglect the mass of the bar.

An applied force moves the bar to the right at a constant speed of 6 m/s. Assume the bar and rails have negligible resistance and friction.

Calculate the applied force required to move the bar to the right at a constant speed.
of 6 m/s.
Correct answer: 54.8571 N.

**Explanation:**

Let: $R = 7 \, \Omega$, 
$B = 1 \, \text{T}$, 
$\ell = 8 \, \text{m}$, and 
$v = 6 \, \text{m/s}$.

Motional emf: $\mathcal{E} = B \ell v$.
Magnetic force on current: $\vec{F} = I \ell \times \vec{B}$.
Ohm’s Law: $I = \frac{V}{R}$.

The motional emf induced in the circuit is

$$\mathcal{E} = B \ell v = (1 \, \text{T}) (8 \, \text{m}) (6 \, \text{m/s}) = 48 \, \text{V}.$$ 

From Ohm’s law, the current flowing through the resistor is

$$I = \frac{\mathcal{E}}{R} = \frac{48 \, \text{V}}{7 \, \Omega} = 6.85714 \, \text{A}.$$ 

Thus, the magnitude of the force exerted on the bar due to the magnetic field is

$$F_B = I \ell B = (6.85714 \, \text{A})(8 \, \text{m})(1 \, \text{T}) = 54.8571 \, \text{N}.$$ 

To maintain the motion of the bar, a force must be applied on the bar to balance the magnetic force

$$F = F_B = 54.8571 \, \text{N}.$$ 

---

**009 (part 1 of 3) 10.0 points**

The resistance of the rectangular current loop is $R$, and the metal rod is sliding to the left. The length of the rod is $d$, while the width of the magnetic region is $\ell$.

Note: $a$ and $b$ are the contact points where the rod touches the rails, and $d > \ell$.

Consider the relationship between the potentials $V_b$ and $V_a$ and the direction of the induced magnetic field.

Which is the correct pair?

1. $V_b > V_a$ and $\hat{B}$ is into the page. **Correct**
2. $V_a > V_b$ and $\hat{B}$ is out of the page.
3. $V_b = V_a$ and $\hat{B}$ is out of the page.
4. $V_b > V_a$ and $\hat{B}$ is down
5. $V_a > V_b$ and $\hat{B}$ is up
6. $V_b > V_a$ and $\hat{B}$ is out of the page.
7. $V_b = V_a$ and $\hat{B}$ is into the page.
8. $V_a > V_b$ and $\hat{B}$ is into the page.
9. $V_a > V_b$ and $\hat{B}$ is down
10. $V_b = V_a$ and $\hat{B}$ is up

**Explanation:**

Note: The part of the rod which extends past the rails does not have a bearing on the answers.

Lenz’s law states that the induced current appears such that it opposes the change in the magnetic flux. In this case the magnetic flux through the rectangular loop is decreasing (since the area of the loop is decreasing), so that the induced magnetic field must point out of the page. This corresponds to
an induced current which flows in a counterclockwise direction. Hence, if you look at the potential drop across the resistor, then you can see that the potential at \( a \) is greater than the potential at \( b \), and the direction of the induced current is \( \text{down} \) through the metal rod.

---

**010** (part 2 of 3) 10.0 points

What is the magnitude of the induced current around the loop?

1. \(|I_{\text{ind}}| = \frac{B d v}{R}\)
2. \(|I_{\text{ind}}| = \frac{B d v^2}{R}\)
3. \(|I_{\text{ind}}| = \frac{B \ell v^2}{R^2}\)
4. \(|I_{\text{ind}}| = \frac{B \ell v^2}{R}\)
5. \(|I_{\text{ind}}| = \frac{B d v}{R^2}\)
6. \(|I_{\text{ind}}| = \frac{B \ell v}{R^2}\)
7. \(|I_{\text{ind}}| = \frac{B d v^2}{R^2}\)
8. \(|I_{\text{ind}}| = \frac{B d^2 v}{R}\)
9. \(|I_{\text{ind}}| = \frac{B \ell v}{R} \text{ correct}\)
10. \(|I_{\text{ind}}| = \frac{B \ell^2 v}{R}\)

**Explanation:**

The rate of change of the area of the rectangular loop is

\[
\frac{dA}{dt} = \ell \frac{dx}{dt}.
\]

Then from Faraday’s law, the magnitude of the induced emf is given by

\[
\mathcal{E} = B \ell v.
\]

From Ohm’s law, \( \mathcal{E} = IR \) so the magnitude of the induced current is

\[
I_{\text{ind}} = \frac{\mathcal{E}}{R} = \frac{B \ell v}{R}.
\]

---

**011** (part 3 of 3) 10.0 points

**Let:** \( B = 54 \text{ T}, R = 899 \Omega, \ell = 0.6 \text{ m}, d = 0.7 \text{ m}.\)

What is the magnetic force exerted on the sliding rod?

**Correct answer:** 3.50309 N.

**Explanation:**

The magnitude of the magnetic force exerted on the metal rod is given by

\[
F = I \ell B,
\]

where \( I \) is the induced current found in Part 2.

**Note:** \( \ell \) was used since \( \vec{B} = 0 \) outside the rectangle.

Substituting in the expression for the induced current yields

\[
F = \frac{B^2 \ell^2 v}{R} = \frac{(54 \text{ T})^2 (0.6 \text{ m})^2 (3 \text{ m/s})}{(899 \Omega)} = 3.50309 \text{ N}.
\]

The direction of the induced current is \( \text{down} \) through the metal rod as explained in Part 1.

---

**012** 10.0 points

A plane loop of wire of area \( A \) is placed in a region where the magnetic field is perpendicular to the plane. The magnitude of \( B \) varies in time according to the expression \( B = B_0 e^{-at} \).

That is, at \( t = 0 \) the field is \( B_0 \), and for \( t > 0 \), the field decreases exponentially in time.

Find the induced emf, \( \mathcal{E} \), in the loop as a function of time.

1. \( \mathcal{E} = a B_0 t \)
2. \( \mathcal{E} = a B_0 e^{-at} \)
3. \( \mathcal{E} = A B_0 e^{-at} \)
4. \( \mathcal{E} = a A B_0 e^{-2at} \)
5. \( \mathcal{E} = a A B_0 \)
6. $E = a A B_0 e^{-at}$ correct

Explanation:

Basic Concepts: Faraday’s Law:

$$E \equiv \oint E \cdot ds = - \frac{d\Phi_B}{dt}$$

Solution: Since B is perpendicular to the plane of the loop, the magnetic flux through the loop at time $t > 0$ is

$$\Phi_B = B A$$
$$= A B_0 e^{-at}$$

Also, since the coefficient $AB_0$ and the parameter $a$ are constants, and Faraday’s Law says

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

the induced emf can be calculated from the Equation above:

$$E = - \frac{d\Phi_B}{dt}$$
$$= - A B_0 \frac{d}{dt} e^{-at}$$
$$= a A B_0 e^{-at}$$

That is, the induced emf decays exponentially in time.

Note: The maximum emf occurs at $t = 0$, where $E = a A B_0$.

The plot of $E$ versus $t$ is similar to the $B$ versus $t$ curve shown in the figure above.

The magnitude of the current, $I_m$, in middle resistor, $R_m$?
Correct answer: 0.718609 A.

Explanation:

Basic Concept: Faraday’s Law:

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

Ohm’s Law:

$$I = \frac{V}{R}$$

Junction Rule:

$$\sum_{i=1}^{n} I_i = 0$$

Solution: Note: The side-length, $a$, of the circuit loop is not necessary for this problem. Neither is the magnitude of $B$ at time $t = 0$.

From Faraday’s law, the induced emf in the left loop (Loop 1) is

$$|E_1| = \frac{d\Phi_B}{dt}$$
$$= A_1 \frac{dB}{dt}$$
$$= \pi r_1^2 \frac{dB}{dt}$$
$$= 10.8071 \text{ V}$$
and the direction of this emf is counterclockwise. Similarly, the induced emf in the right loop (Loop 2) is

\[ |\mathcal{E}_2| = \frac{d\Phi_B}{dt} = A_2 \frac{dB}{dt} = \pi r_2^2 \frac{dB}{dt} = 2.70177 \text{ V} \]

and the direction of this emf is clockwise.

(Numerical values are inserted into the equations to verify answers; our calculation has only 7 place accuracy.) Moving clockwise around the loops, circuit equations for these two loops are

**Loop 1:**

\[-R_l I_l + R_m I_m - \mathcal{E}_1 = 0 \quad (1)\]

\[-(8.8 \, \Omega)(-0.893271 \, \text{A}) + (4.1 \, \Omega)(0.718609 \, \text{A}) - 10.8071 \, \text{V} = 0.\]

**Loop 2:**

\[-R_m I_m + R_r I_r + \mathcal{E}_2 = 0 \quad (2)\]

\[-(4.1 \, \Omega)(0.718609 \, \text{A}) + (1.4 \, \Omega)(-0.174662 \, \text{A}) + 2.70177 \, \text{V} = -0.489053 \, \text{V}.\]

From the junction rule, we have

\[ I_l + I_m + I_r = 0 \]

Solving these three simultaneous equations (Eqs. 1, 2, and 3) yields

\[ I_m = 0.718609 \, \text{A}, \]
\[ I_r = -0.174662 \, \text{A}, \quad \text{and} \]
\[ I_l = -0.893271 \, \text{A}. \]

**015 (part 1 of 3) 10.0 points**

A pendulum consists of a supporting rod and a metal plate (see figure). The rod is pivoted at \( O \). The metal plate swings through a region of magnetic field. Consider the case where the pendulum is entering the magnetic field region from the left.

**Explanation:**

The right-hand rule tells us that the field produced by the left solenoid is increasing in a direction into the page. Lenz’s law tells us that the current in the left loop will oppose this increase in flux and produce a current counter-clockwise. Thus, the current in the middle resistor will be up as shown.

The right-hand rule tells us that the field produced by the right solenoid is increasing in a direction out of the page. Lenz’s law tells us that the current in the right loop will oppose this increase in flux and produce a current clockwise. Thus, the current in the middle resistor will be up as shown.

Since both solenoids produce a current in the middle resistor in the same direction as shown by the arrow in the diagram, so be it.

This result is verified by the plus sign for the current \( I_m = 0.718609 \, \text{A} \), when solving the simultaneous Eqns. (1), (2), and (3).
The direction of the circulating eddy current in the plate is

1. clockwise. **correct**
2. counter-clockwise.

**Explanation:**
Using the right-hand rule the circulating eddy current in the plate is clockwise.

---

**016 (part 2 of 3) 10.0 points**
The direction of the induced magnetic field at the center of the circulating eddy current is

1. along the rod toward $O$.
2. out of the paper.
3. parallel to the direction of motion; *i.e.*, the arrow in the sketch.
4. along the rod away from $O$.
5. into the paper. **correct**

**Explanation:**
Because the magnetic field is pointing out of the paper, the induced flux of the portion of the plate entering the magnetic region should be into the paper. Hence, by the right hand rule, the induced current is clockwise.

---

**017 (part 3 of 3) 10.0 points**
The direction of the force which the magnetic field exerts is

1. along the rod toward the pivot point.
2. out of the paper.
3. along the direction of swing.
4. opposite to the direction of swing. **correct**
5. into the paper.

**Explanation:**
Because the magnetic field only exerts a force on the current segment already in the magnetic field region, the net magnetic force is opposite to the direction of swing, see the figure in the explanation of the previous Part.

---

**018 (part 1 of 4) 10.0 points**
A rectangular loop with resistance $R$ has $N$ turns, each of length $L$ and width $W$ as shown in the figure. The loop moves into a uniform magnetic field $B$ (out of the page) with speed $v$.

What is $\frac{d\Phi_{\text{total}}}{dt}$ (the time derivative of the flux for all turns of the loop) just after the front edge (side $ab$) of the loop enters the field?

1. $\frac{d\Phi_{\text{total}}}{dt} = N B W v$ **correct**
2. $\frac{d\Phi_{\text{total}}}{dt} = N B W L v$
3. \[
\frac{d \Phi_{\text{total}}}{dt} = N B W L
\]
4. \[
\frac{d \Phi_{\text{total}}}{dt} = B W L v
\]
5. \[
\frac{d \Phi_{\text{total}}}{dt} = \text{zero}
\]
6. \[
\frac{d \Phi_{\text{total}}}{dt} = B W v
\]
7. \[
\frac{d \Phi_{\text{total}}}{dt} = N B L v
\]
8. \[
\frac{d \Phi_{\text{total}}}{dt} = N B W
\]
9. \[
\frac{d \Phi_{\text{total}}}{dt} = B L v
\]
10. \[
\frac{d \Phi_{\text{total}}}{dt} = N B L
\]

**Explanation:**

\[
\Phi = \vec{B} \cdot \vec{A}
\]

\[
\Phi_{\text{total}} = N \Phi = N [\vec{B} \cdot \vec{A}]
\]

The magnetic flux is given by

\[
\Phi_{\text{total}} = N (B \cdot A),
\]
where \(N\) and \(B\) are constant, but the area is changing.

\(A = W (v t)\) initially, so

\[
\Phi_{\text{total}} = N B W v t
\]

\[
\frac{d \Phi_{\text{total}}}{dt} = N B W v.
\]

---

**019 (part 2 of 4) 10.0 points**

What is the direction of the current \(I\) in the loop just after it enters the magnetic field?

1. clockwise **correct**
2. counter-clockwise
3. No current

**Explanation:**

Apply Lenz’ Law, that is the induced current is in the direction that will generate a magnetic field that will oppose the change in flux. As more of the loop enters the field region it picks up more flux out of the page, hence the induced current should generate an opposite field. Applying the right hand rule, the current must be clockwise.

---

**020 (part 3 of 4) 10.0 points**

Given: \(I\) is the current as found in Part 2.

What is the magnitude of the force \(F\) on the loop just after the front edge (side \(ab\)) of the loop enters the field?

1. \[\| \vec{F} \| = \frac{N^2 B^2 W^2 L v}{R}\]
2. \[\| \vec{F} \| = \frac{N^2 B^2 W}{R v}\]
3. \[\| \vec{F} \| = \frac{N^2 B^2 W v}{R}\]
4. \[\| \vec{F} \| = \frac{N^2 B^2 W L v}{R}\]
5. \[\| \vec{F} \| = \frac{N^2 B^2 W^2 R}{v}\]
6. \[\| \vec{F} \| = \frac{N^2 W^2 R v}{B^2}\]
7. \[\| \vec{F} \| = \frac{N^2 B^2 W^2 v}{R}\] **correct**
8. \[\| \vec{F} \| = \frac{N^2 B^2 W^2 L v}{R^2}\]
9. \[\| \vec{F} \| = \frac{N^2 B^2 R}{W^2 v}\]
10. \[\| \vec{F} \| = \text{zero}\]

**Explanation:**

The force on the loop is given by \(F = N I B W = \frac{N^2 B^2 W^2 v}{R}\) as the forces act on the current within the field, and the horizontal currents have equal and opposite forces. Thus only the left hand vertical loops have a force acting on them. This force acts to oppose the movement of the coils, and must point right.

---

**021 (part 4 of 4) 10.0 points**
What is the magnitude of the force $F$ on the loop as it moves within the field?

1. $\| \vec{F} \| = \frac{N^2 B^2 W^2 R}{v}$
2. $\| \vec{F} \| = \frac{N^2 B^2 W^2 v}{R}$
3. $\| \vec{F} \| = \frac{N^2 W^2 R v}{B^2}$
4. $\| \vec{F} \| = \frac{N^2 B^2 W v}{R}$
5. $\| \vec{F} \| = 0$ correct
6. $\| \vec{F} \| = \frac{N^2 B^2 W L v}{R}$
7. $\| \vec{F} \| = \frac{N^2 B^2 W^2 L v}{R^2}$
8. $\| \vec{F} \| = \frac{N^2 B^2 W}{R v}$
9. $\| \vec{F} \| = \frac{N^2 B^2 W^2 L v}{R}$
10. $\| \vec{F} \| = \frac{N^2 B^2 R}{W^2 v}$

Explanation:
Within the field, the magnetic flux is constant, so $\frac{d \Phi^{\text{total}}}{dt} = 0$. Thus, $\mathcal{E} = 0$, $I = 0$, and no force opposes the motion.