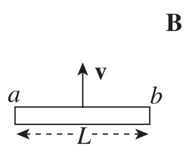
Chapter 16 Drill

The answers and explanations can be found in Chapter 17.

Section I: Multiple Choice

1. A metal rod of length L is pulled upward with constant velocity $\mathbf{v}$ through a uniform magnetic field $\mathbf{B}$ that points out of the plane of the page.



What is the potential difference between points a and b ?

(A) 0

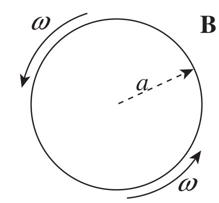
(B) $\frac{1}{2}v\,BL$, with point a at the higher potential

(C) $\frac{1}{2}v\,BL$, with point b at the higher potential

(D) vBL, with point a at the higher potential

(E) vBL, with point b at the higher potential

2. A circular disk of radius a is rotating at a constant angular speed ω in a uniform magnetic field, $\mathbf{B}$, which is directed out of the plane of the page.



Determine the induced emf between the center of the disk and the rim.

(A) $\frac{1}{2}\omega\mathbf{B}a$

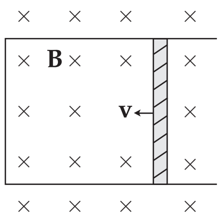
(B) $\frac{1}{2}\mathbf{B}a$

(C) $\frac{1}{2}\omega\mathbf{B}a^2$

(D) $\omega\mathbf{B}a^2$

(E) $2\pi\omega\mathbf{B}a^2$

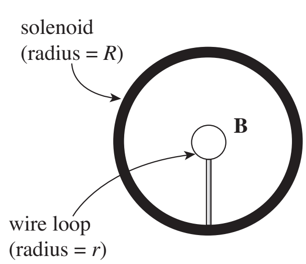
3. A conducting rod of length 0.2 m and resistance 10 Ω between its endpoints slides without friction along a U-shaped conductor in a uniform magnetic field B of magnitude 0.5 T perpendicular to the plane of the conductor, as shown in the diagram below.



If the rod is moving with velocity **v** = 3 m/s to the left, what is the magnitude and direction of the current induced in the rod?

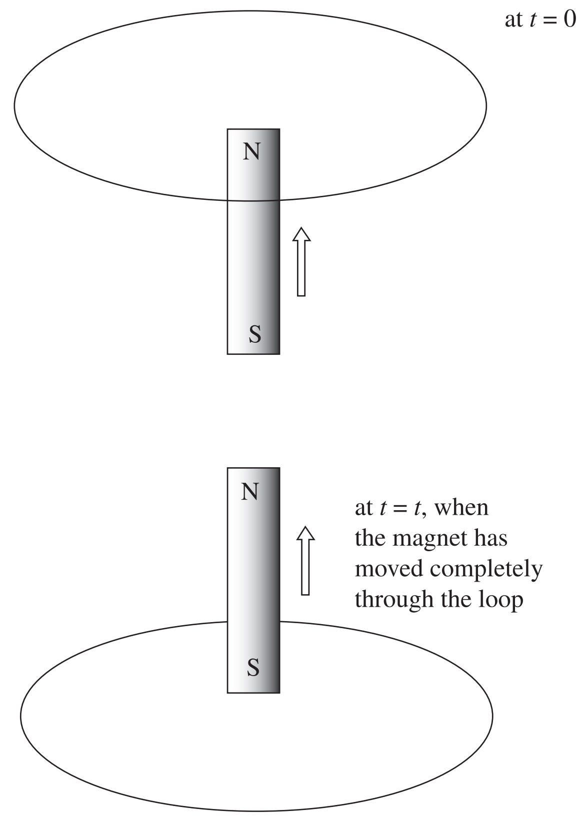
Current	Direction
(A) 0.03 A	down
(B) 0.03 A	up
(C) 0.3 A	down
(D) 0.3 A	up
(E) 3 A	down

4. In the figure below, a small, circular loop of wire (radius r) is placed on an insulating stand inside a hollow solenoid of radius R. The solenoid has n turns per unit length and carries a current I. If the current in the solenoid is decreased at a steady rate of a amps/s, determine the induced emf, ε, and the direction of the induced current in the loop.



(A) $\varepsilon = \mu_0 \pi n r^2 a$; induced current is clockwise
(B) $\varepsilon = \mu_0 \pi n r^2 a$; induced current is couterclockwise
(C) $\varepsilon = \mu_0 \pi n R^2 a$; induced current is clockwise
(D) $\varepsilon = \mu_0 \pi n R^2 a$; induced current is couterclockwise
(E) $\varepsilon = \mu_0 \pi I n R^2 a$; induced current is counterclockwise

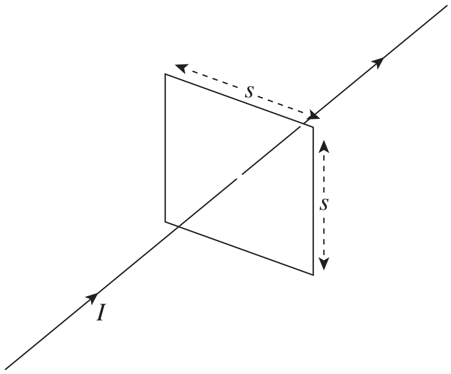
5. In the figure below, a permanent bar magnet is pulled upward with a constant velocity through a loop of wire.



Which of the following best describes the direction(s) of the current induced in the loop (looking down on the loop from above)?

(A) Always clockwise
(B) Always counterclockwise
(C) First clockwise, then counterclockwise
(D) First counterclockwise, then clockwise
(E) No current will be induced in the loop.

6. A square loop of wire (side length = s) surrounds a long, straight wire such that the wire passes through the center of the square.



If the current in the wire is I, determine the current induced in the square loop.

(A) $\dfrac{2\mu_0 Is}{\pi\left(1+\sqrt{2}\right)}$

(B) $\dfrac{\mu_0 Is}{\pi\sqrt{2}}$

(C) $\dfrac{\mu_0 Is}{\pi}$

(D) $\dfrac{\mu_0 Is\sqrt{2}}{\pi}$

(E) 0

<u>Questions 7-9</u>

A circuit contains a solenoid of inductance L in series with a resistor of resistance R and a battery with terminal voltage ε. At time $t = 0$, a switch is closed and the circuit is completed.

7. How long does it take for the current to reach $\frac{3}{4}$ of its maximum (steady-state) value?

(A) (ln 4)(L/R)

(B) (ln $\frac{3}{4}$)(L/R)

(C) (ln $\frac{4}{3}$)(L/R)

(D) (ln $\frac{4}{3}$)(R/L)

(E) (ln 4)(R/L)

8. When the current reaches its maximum value, how much energy is stored in the magnetic field of the solenoid?

(A) $L^2\mathcal{E}^2/(4R^2)$
(B) $L^2\mathcal{E}^2/(2R^2)$
(C) $L\mathcal{E}^2/(4R^2)$
(D) $L\mathcal{E}^2/(2R^2)$
(E) 0

9. When the current reaches its maximum value, what is the total magnetic flux through the solenoid?

(A) $L\mathcal{E}$
(B) $L\mathcal{E}/R$
(C) $\mathcal{E}/(RL)$
(D) $RL/\mathcal{E}$
(E) 0

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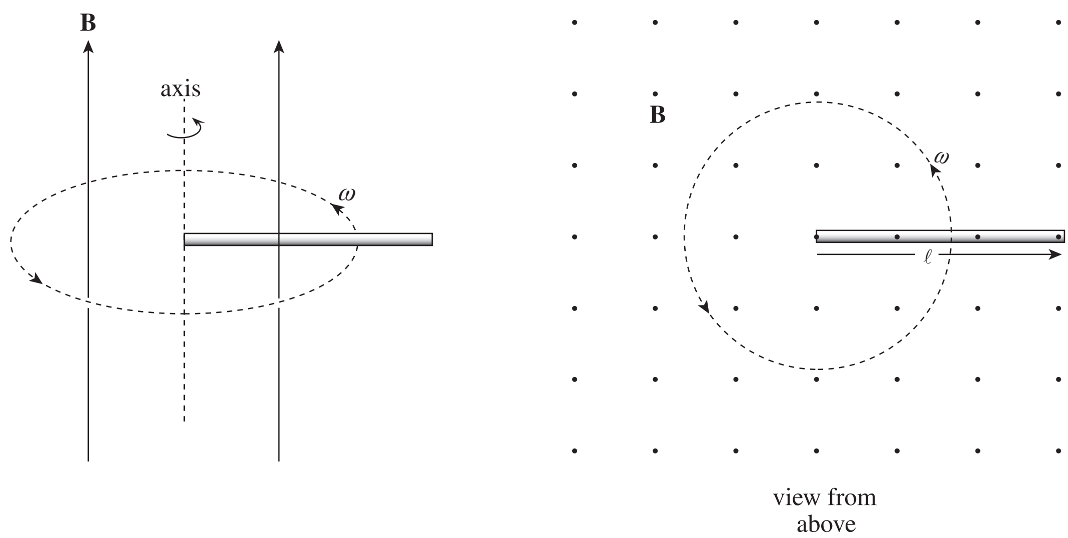
10. Which one of Maxwell's equations states that a changing electric field produces a magnetic field?

(A) Gauss's law
(B) Gauss's law for magnetism
(C) Biot–Savart law
(D) Ampere–Maxwell law
(E) Faraday's law

Section II: Free Response

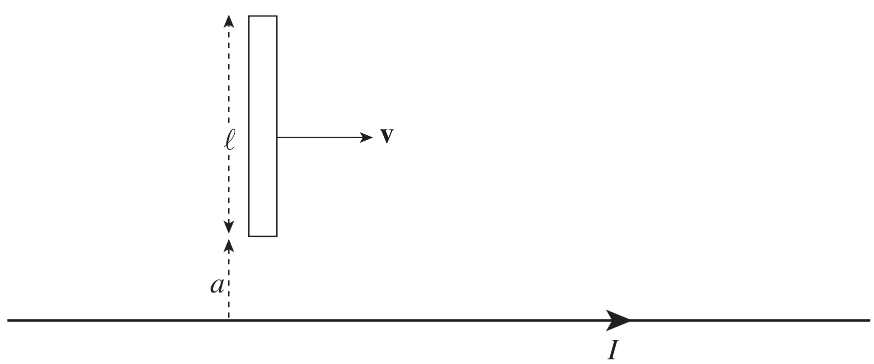
1. The diagram below shows two views of a metal rod of length ℓ rotating with constant angular speed ω about an axis that is in the plane of the page. The rotation takes place in a uniform magnetic field **B** whose direction is parallel to the angular velocity ω.



(a) What is the emf induced between the ends of the rod?

(b) What is the polarity (+ or –) of the rotating end?

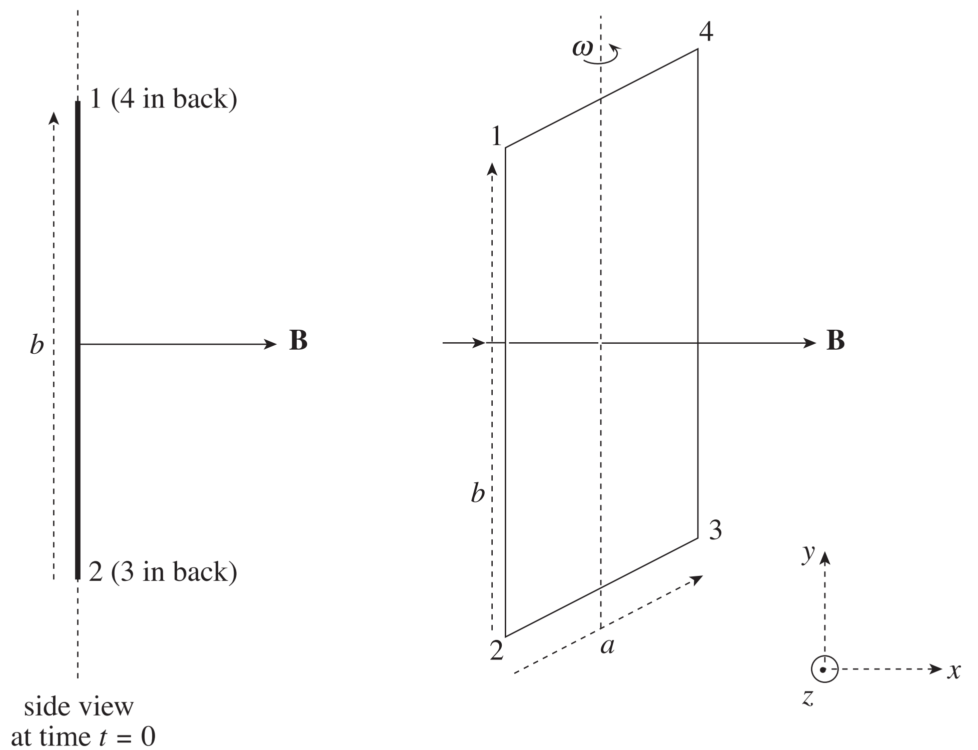
In the following diagram, a metal rod of length ℓ moves with constant velocity **v** parallel to a long, straight wire carrying a steady current *I*. The lower end of the rod maintains a distance of *a* from the straight wire.



(c) What is the emf induced between the ends of the rod?

(d) What is the polarity (+ or –) of the end that is farther from the straight wire?

2. A rectangular loop of wire (side lengths a and b) rotates with constant angular speed ω in a uniform magnetic field **B**. At time $t = 0$, the plane of the loop is perpendicular to **B**, as shown in the figure on the left. The magnetic field **B** is directed to the right (in the $+x$ direction), and the rotation axis is the y-axis (with ω in the $+y$ direction), and the four corners of the loop are labeled 1, 2, 3, and 4. (Express answers in terms of a, b, ω, B, and fundamental constants.)



(a) Find a formula that gives the magnetic flux **ΦB** through the loop as a function of time, t.

(b) Find a formula that gives the emf induced in the loop as a function of time, t.

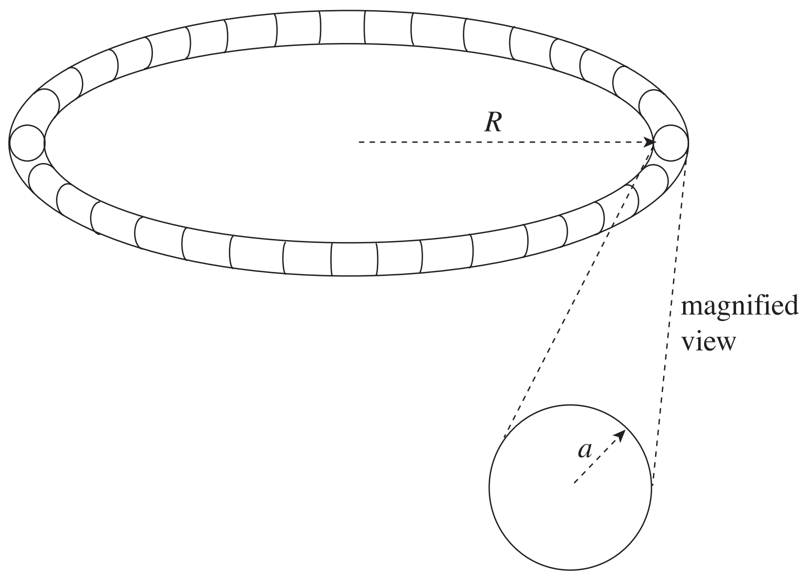
(c) If the total resistance of the loop is R, what is the current induced in the loop?

(d) When $\omega t = \pi/2$, is the induced current in the loop directed from Point 1 to Point 2 ($-y$ direction) or from Point 2 to Point 1 ($+y$ direction)?

(e) Find the rate at which energy is dissipated (as joule heat) in the wires that comprise the loop, and the amount of energy dissipated per revolution.

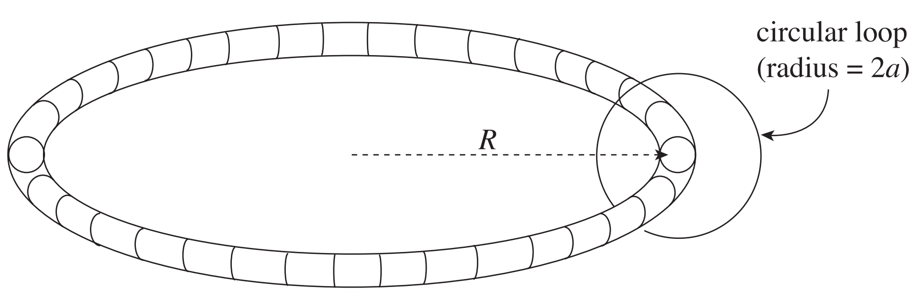
(f) Find the external torque required to keep the loop rotating at the constant angular speed ω.

3. The figure below shows a toroidal solenoid of mean radius R and N total windings. The cross-sections of the toroid are circles of radius a (which is much smaller than R, so variations in the magnetic field strength within the space enclosed by the windings may be neglected).



(a) Use Ampere's law to find the magnetic field strength within the toroid. Write your answer in terms of N, I, R, and fundamental constants.

A circular loop of wire of radius $2a$ is placed around the toroid as shown:

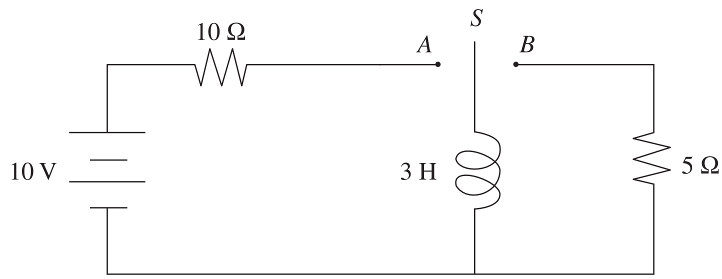


Assume that the current in the toroid is varied sinusoidally according to the equation $I(t) = I_0 \sin \omega t$, where I_0 and ω are fixed constants.

(b) Determine the emf induced in the circular wire loop.

(c) Determine the electric field induced at the position of the circular wire loop.

(d) What is the self-inductance of the toroidal solenoid?



4. A circuit is connected as shown above. The switch S is initially open. Then it is moved to position A.

(a) Determine the current in the circuit immediately after the switch is closed.

(b) Determine the current in the circuit a long time after the switch is closed.

Some time after the steady state situation has been reached, the switch is moved almost instantaneously from position A to position B.

(c) Determine the current through the 5 Ω resistor immediately after the switch has been moved.

(d) Determine the potential difference across the inductor immediately after the switch has been closed.