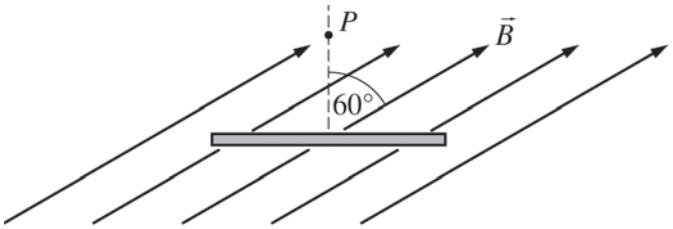
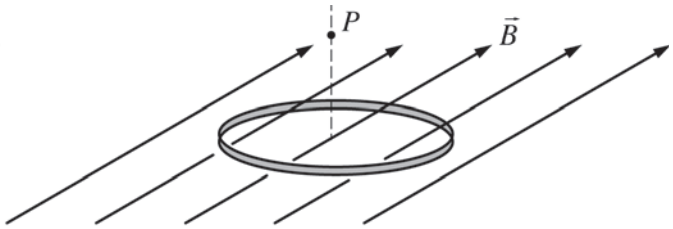


Edge View



Perspective View

E&M. 3.

A circular wire loop with radius 0.10 m and resistance 50 Ω is held in place horizontally in a magnetic field $\vec{B}$ directed upward at an angle of 60° with the vertical, as shown in the figure above. The magnetic field in the direction shown is given as a function of time t by $B(t) = a(1 - bt)$, where $a = 4.0$ T and $b = 0.20\ s^{-1}$.

(a) Derive an expression for the magnetic flux through the loop as a function of time t.

(b) Calculate the numerical value of the induced emf in the loop.

(c)

i. Calculate the numerical value of the induced current in the loop.

ii. What is the direction of the induced current in the loop as viewed from point P ?

____ Clockwise ____ Counterclockwise

Justify your answer.

(d) Assuming the loop stays in its current position, calculate the energy dissipated in the loop in 4.0 seconds.

(e) Indicate whether the net magnetic force and net magnetic torque on the loop are zero or nonzero while the loop is in the magnetic field.

Net magnetic force: ____ Zero ____ Nonzero

Net magnetic torque: ____ Zero ____ Nonzero

Justify both of your answers.

STOP

END OF EXAM

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Question 3

15 points total **Distribution of points**

(a) 3 points

For properly using a correct equation to calculate the magnetic flux 1 point

$\Phi_B = \int \vec{B} \bullet d\vec{A}$

For correct substitution of the area and trigonometric function 1 point

$\Phi_B = BA(\cos\theta) = B\pi r^2(\cos\theta)$

For correct substitution into the above equation 1 point

$\Phi_B = 4(1 - 0.2t)\pi(0.10\text{ m})^2(\cos 60°)$

$\Phi_B = 0.063 - 0.013t$ (or in terms of a and b, $\Phi_B = a(1 - bt)(0.016)$)

(b) 2 points

For using a correct equation to solve for the emf 1 point

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

Substituting the expression from part (a):

$\mathcal{E} = \frac{d}{dt}(0.063 - 0.013t)$

For an answer consistent with part (a) 1 point

$\mathcal{E} = 0.013\text{ V}$

Note: Any sign on the answer is ignored.

(c)

i. 1 point

For a substitution into Ohm's law consistent with the answer from part (b) 1 point

$V = IR$

$I = \frac{(0.013\text{ V})}{(50\ \Omega)}$

$I = 2.6 \times 10^{-4}\text{ A}$

ii. 2 points

The correct choice is "Counterclockwise".

For a justification that incorporates that the original magnetic field is changing 1 point

For a justification that correctly relates the induced current to the direction of a new magnetic field created by that current 1 point

Example: Looking down at the loop from *P*, the vertical component of the magnetic field of the loop is upward and decreasing. To oppose this change, the current in the loop must create a magnetic field that is directed upward at point *P*. This requires a counterclockwise current in the loop.

Question 3 (continued)

Distribution of points

(d) 2 points

For using a correct equation to calculate the energy dissipated — 1 point

$E = Pt = I^2Rt$ or $E = Pt = \left(\mathcal{E}^2/R\right)t$

For a substitution into either of the above equations with the answer from part (c)(i) or part (b) — 1 point

$E = \left(2.6 \times 10^{-4}\ \text{A}\right)^2 (50\ \Omega)(4.0\ \text{s})$ or $E = \dfrac{(0.013\ \text{V})^2}{(50\ \Omega)}(4.0\ \text{s})$

$E = 1.4 \times 10^{-5}\ \text{J}$

(e) 4 points

For selecting both "Zero" for the net magnetic force and "Nonzero" for the Net magnetic torque — 1 point

For indicating the forces on directly opposite sides of the loop are in opposite directions — 1 point

For concluding that the forces cancel & net force is zero — 1 point

For indicating that the torques add & net torque is nonzero — 1 point

Example: Since the current changes direction relative to the magnetic field as you go around the loop, the magnetic field will exert force of equal magnitude but opposite direction on opposite sides of the loop. These forces all cancel out resulting in zero net force. However, since this force is up on one side of the loop and down on the other side of the loop, this will create torques that rotate the loop in the same direction. Therefore, the net torque is not zero.

Units 1 point

For correct units on at least two parts with a calculated numerical answer and no incorrect units — 1 point