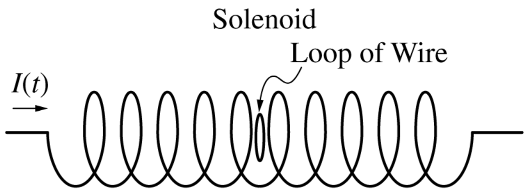
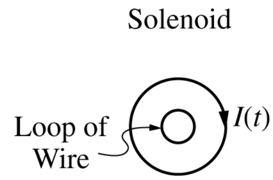
Begin your response to **QUESTION 3** on this page.



Side View



End View

Note: Figures not drawn to scale.

3. A single loop of wire with resistance $3.0\ \Omega$ and radius $0.10\ \text{m}$ is placed inside a solenoid, with the normal to the loop parallel to the axis of the solenoid. The solenoid has 500 turns, is $0.25\ \text{m}$ long, and is connected to a power supply that is not shown. At time $t = 0$, the power supply is turned on, and the current I in the solenoid as a function of t is given by the equation $I(t) = \beta t$, where $\beta = 5.0\ \text{A/s}$. The direction of the current in the solenoid is clockwise, as shown in the end view.

(a) At time $t = 2.0\ \text{s}$, is the induced current in the loop, as seen from the end view shown, clockwise, counterclockwise, or zero?

___ Clockwise ___ Counterclockwise ___ Zero

Justify your answer.

(b) Calculate the current in the loop of wire at time $t = 2.0\ \text{s}$.

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(c) Calculate the total energy dissipated by the loop of wire from time $t = 0$ to time $t = 2.0\text{ s}$.

(d) A group of students attempts to verify experimentally the calculation of the current from part (b). The current in the inner circular loop at time $t = 2.0\text{ s}$ is measured to be less than the current calculated in part (b). Which of the following could explain this discrepancy? Select one answer.

___ The experiment did not account for Earth's magnetic field.
___ The plane of the loop is not perpendicular to the axis of the solenoid.
___ The center of the loop is not on the axis of the solenoid.
___ The resistance of the loop is less than the given value.
___ The radius of the loop is actually larger than 0.10 m.

Justify your answer.

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(e) The power supply is now turned off. The original loop of wire is then replaced with a second loop made from wire that has the same thickness and is made from the same material as the original loop of wire. The second loop has radius 0.20 m, is placed in the same orientation as the original loop, and fits completely inside the solenoid. The power supply is turned on, and the current I in the solenoid as a function of t is again given by the equation $I(t) = \beta t$, where $\beta = 5.0$ A/s. Which of the following expressions correctly indicates the ratio $\frac{I_2}{I_1}$ where I_1 represents the current induced in the original loop of wire in part (b) and I_2 represents the current induced in the second loop of wire?

___ $\frac{I_2}{I_1} = 1$ ___ $1 < \frac{I_2}{I_1} < 2$ ___ $\frac{I_2}{I_1} = 2$ ___ $\frac{I_2}{I_1} > 2$

Justify your answer.

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Example Response

The magnetic flux quadruples. This is because of the increase in area of the loop, which quadruples the emf. The resistance of the loop doubles because the length of the wire doubles. Therefore, $\frac{I_2}{I_1} = 2$.

$$\varepsilon = \mu_0 n\left(A_{loop}\right) = \mu_0 n\left(\pi r^2\right)\frac{dI}{dt}$$

The radius of the loop doubles. Therefore, the area of the loop quadruples.

$$R = \rho\frac{2\pi r}{A_{wire}}$$

The radius of the loop doubles. Therefore, the resistance of the loop doubles.

$$\frac{I_2 = \frac{\varepsilon}{R} = \frac{\mu_0 n(4)A}{(2)R}\frac{dI}{dt}}{I_1 = \frac{\varepsilon}{R} = \frac{\mu_0 nA}{R}\frac{dI}{dt}} = 2$$

Total for part (e) 3 points

Total for question 3 15 points