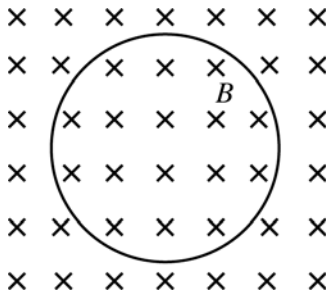
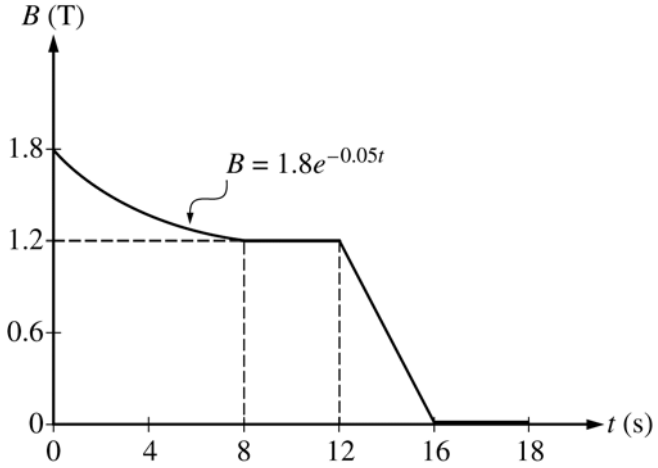


E&M 3.

The figure above shows a circular loop of area $0.25\ \text{m}^2$ and resistance $12\ \Omega$ that lies in the plane of the page. A magnetic field of magnitude B directed into the page exists in the area of the loop. The field varies with time t, as shown in the graph below.



(a)

i. Derive an expression for the magnitude of the induced emf in the loop as a function of time for the interval $t = 0$ s to $t = 8$ s.

ii. Calculate the magnitude of the induced current I in the loop at time $t = 4$ s.

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Question 3

15 points total **Distribution of points**

(a)

i. 3 points

For using a correct expression of Faraday's law 1 point

$\mathcal{E} = -d\phi/dt$

For correct substitution of area and magnetic field into Faraday's law 1 point

$\mathcal{E} = -A[dB/dt] = -A\left[d\left(1.8e^{-0.05t}\right)/dt\right]$

Taking the derivative and substituting values

$\mathcal{E} = -\left(0.25\ \text{m}^2\right)(-0.05)(1.8)e^{-0.05t}$

For a correct answer 1 point

$\mathcal{E} = 0.0225e^{-0.05t}\ \text{V}$

Note: The negative sign is not needed in the calculations because the question asked for the magnitude of the emf

ii. 1 point

Use Ohm's law

$I = V/R$

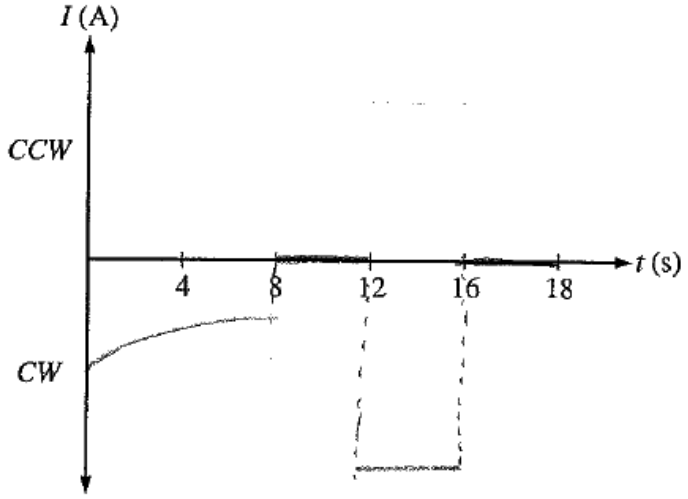
For using the expression from (a) in Ohm's law with the correct time 1 point

$I = (0.0225)\left(e^{(-0.05)(4\ \text{s})}\right)/12\ \Omega$

$I = 0.00154\ \text{A}$ or $1.54\ \text{mA}$

(b)

i. 4 points



For indicating a current that decays exponentially in the region $0\ \text{s} < t < 8\ \text{s}$ 1 point

For indicating a current of zero in the regions $8\ \text{s} < t < 12\ \text{s}$ and $t > 16\ \text{s}$ 1 point

For indicating a current that is constant and nonzero in the region $12\ \text{s} < t < 16\ \text{s}$ 1 point

Question 3 (continued)

Distribution of points

For indicating a clockwise current in the regions $0\text{ s} < t < 8\text{ s}$ and $12\text{ s} < t < 16\text{ s}$ 1 point

ii. 3 points

For indicating that magnetic field is decreasing 1 point
For indicating that an induced magnetic field opposes the change 1 point
For indicating that the induced current must be clockwise to produce the induced magnetic field 1 point

Example:
The magnetic field is into the page and decreasing. From Lenz's law, the new current must create a magnetic field to oppose this change. So the new current must create its own magnetic field that is into the page. Thus, according to the right hand rule, the current in the loop must be clockwise.

Note: 1 earned point was deducted for any incorrect statements made in conjunction with correct statements.

(c) 4 points

For indicating that energy is the integral of power over time 1 point

$$E = \int P dt$$

For using a correct expression of power 1 point

$$E = \int \frac{\mathcal{E}^2}{R} dt$$

For a correct substitution from part (a) 1 point
For using the proper limits on the integration or correctly evaluating a constant of integration 1 point

$$E = \int_0^8 \frac{\left(0.0225 e^{-0.05t}\right)^2}{(12\ \Omega)} dt = \frac{(0.0225)^2}{(12\ \Omega)} \int_0^8 e^{-0.10t} dt$$

$$E = \frac{\left(4.22 \times 10^{-5}\right)}{(-0.10)} \left[e^{-0.10t} \right]_0^8$$

$$E = \left(-4.22 \times 10^{-4}\right)\left(e^{-(0.10)(8\text{ s})} - e^{0}\right)$$

$$E = 2.32 \times 10^{-4}\ \text{J}$$