15-Phys-202

WINTER 2003

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Quiz 7 Name _____

Useful formulae and constants:

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

$$B = \mu_0 n i \text{ (solenoid)}$$

$$\mu_0 = 4\pi \times 10^{-7} \text{ T} \cdot \text{m/A}$$

1. A long solenoid with a radius of 25 mm has 100 turns/cm. A single loop of wire of radius 5.0 cm is placed around the solenoid, the central axes of the loop and the solenoid coinciding. In 10 ms the current in a solenoid is reduced from 1.0 A to 0.50 A at a uniform rate. What emf appears in the loop? *Hint*: magnetic field $\overrightarrow{B}$ only appears inside the solenoid.

   Solution

   The induced emf

   $$\mathcal{E} = -\frac{d\Phi_B}{dt} = --\frac{d(BA)}{dt} = -A\frac{dB}{dt} = -A\frac{d(\mu_0 n i)}{dt} = -A\mu_0 n\frac{di}{dt}$$

   where

   $$A = \pi r^2$$

   and r is the radius of the *solenoid*. Also,

   $$\frac{di}{dt} = \frac{i_{final} - i_{init}}{\Delta t}$$

   where Δt is the time over which the current changed linearly from i_{init} to i_{final}. Combining all of the above expressions,

   $$\begin{aligned}
   \mathcal{E} &= -\mu_0 n \left(\pi r^2\right)\left(\frac{i_{final} - i_{init}}{\Delta t}\right) \\
   &= -\left(4\pi \times 10^{-7}\right)\left(\frac{100}{10^{-2}}\right)\pi\left(25 \times 10^{-3}\right)^2\left(\frac{0.50 - 1.0}{10 \times 10^{-3}}\right) \\
   &= 1.2 \times 10^{-3} \text{ V}
   \end{aligned}$$