University Physics, PHYS 227/232 Quiz 5 Solution Fri Apr 4, 2014

Your name and table number: ______________________

Please show your work, write neatly, write units, and $\boxed{\text{box}}$ your answers.

Magnetic flux: $\Phi_{\rm B} = \int \vec{B} \cdot d\vec{A} = BA\cos\theta$

Faraday's Law: $\mathcal{E} = -d\Phi_B/dt$

Ohm's Law: $V = IR$

Solenoid magnetic field: $B_{\rm sol} = \mu_0 n I$

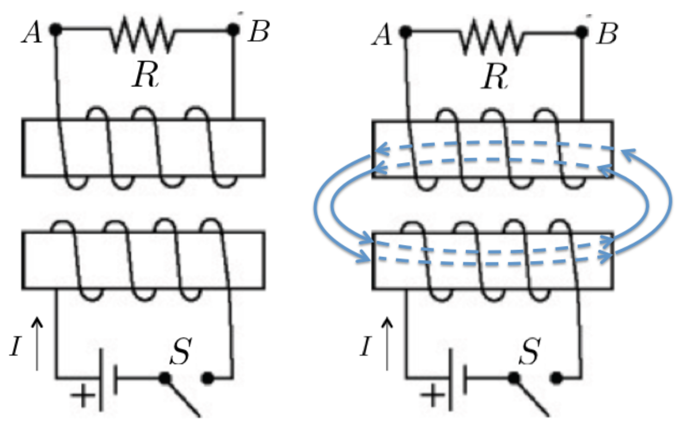
Self-inductance: $L = \Phi_{\rm B}/I = \mu_0 n^2 A/l$

Circumference of circle $= 2\pi r$

Area of circle $= \pi r^2$

Electron charge: $e = 1.602 \times 10^{-19}$ C

Electron mass: $m_{\rm e} = 9.109 \times 10^{-31}$ kg



1. Consider the above figure, where current starts flowing in the indicated direction when the switch S is closed, and stops flowing when the switch S is opened.

   (a) (2 points) A while after the switch is closed, as the current I is *increasing*, is the induced current in the resistor…

   i. … flowing from A to B?

   ii. $\boxed{\text{… flowing from } B \text{ to } A\text{?}}$

   iii. … not flowing in either direction?

   Solution:

   With the current in the indicated direction, the field lines point right in the bottom solenoid, and return to point left in the top solenoid as shown in the colored arrows in the right figure above. (If you wrap your right hand around the direction of the current with your thumb pointing in the direction of the current, your fingers will point to the right inside the bottom solenoid.) The flux through the top solenoid points to the left, in the direction of the field lines. When the current is increasing, this flux is increasing so the change in flux also points to the left here.

   The induced current wants to create a flux that opposes this change! So the induced current wants to create a flux, or magnetic field, pointing to the right (fighting the change in flux pointing to the left). What direction of current in the above solenoid's coil creates this direction of field? A current that goes from B to A.

(b) (2 points) Much later the battery loses charge and the current I is *decreasing*. Is the induced current in the resistor...

   i. $\boxed{\text{... flowing from } A \text{ to } B?}$

   ii. ... flowing from B to A?

   iii. ... not flowing in either direction?

   Solution: The field strength is now *decreasing*, so the flux in the top solenoid is now *decreasing*. That means that the *change* in flux is pointing to the right (opposite the flux itself).

   The induced current wants to create a flux that opposes this change! So the induced current wants to create a flux, or magnetic field, pointing to the eleft (fighting the change in flux pointing to the right). What direction of current in the above solenoid's coil creates this direction of field? A current that goes from A to B.

2. A circular wire loop with *radius* 24 cm has 50 Ω resistance and lies in a horizontal plane. A uniform magnetic field points vertically downward, and in 2.7×10^{-2} seconds it *increases* linearly from 5.0×10^{-3} T to 6.0×10^{-2} T.

   (a) (2 points) Find the magnetic flux Φ_B through the loop at the start when $B = 5.0 \times 10^{-3}$ T.

   Solution: The definition of magnetic flux is

$$\Phi_B \equiv \int \vec{B} \cdot d\vec{A} = BA\cos\theta$$

   Remember that the vector for an area $\vec{A}$ is *perpendicular* or *normal* to the area itself! So the angle between $\vec{B}$ and $\vec{A}$ here is $\theta = 0$ and $\cos\theta = 1$. So

$$\Phi_B = BA = (5.0 \times 10^{-3}\,\mathrm{T})(\pi(0.24\,\mathrm{m})^2) = \boxed{9 \times 10^{-4}\,\mathrm{Wb} = \Phi_B}$$

   (b) (2 points) Find the magnetic flux Φ_B through the loop at the end when $B = 6.0 \times 10^{-2}$ T.

   Solution:

$$\Phi_B = BA = (6.0 \times 10^{-2}\,\mathrm{T})(\pi(0.24\,\mathrm{m})^2) = \boxed{11 \times 10^{-3}\,\mathrm{Wb} = \Phi_B}$$

   (c) (2 points) Calculate the induced EMF $\mathcal{E}$ during the time that the field changes.

   Solution: Here we can use Faraday's Law:

$$\mathcal{E} = -\frac{d\Phi_B}{dt} = -\frac{(11 \times 10^{-3}\,\mathrm{Wb} - 9 \times 10^{-4}\,\mathrm{Wb})}{2.7 \times 10^{-2}\,\mathrm{s}} = \boxed{0.37\,\mathrm{V} = \mathcal{E}}$$