September 28, 2004 – mini-Quiz #3 – 8.03

Your name . . . . .R01 – R02 – R03 – R04 – R05

2 points
A constant current is flowing through a resistor in the direction as indicated in the figure. In going from A to B, we measure $\int_A^B \vec{E} \cdot d\vec{l}$. What do we find?

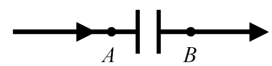
■ a positive value
☐ a negative value
☐ zero
☐ we do not have enough information to answer

1 point
Would there be a difference in the result between going from A to B through the resistor or through the air?

■ no difference
☐ yes, there is a difference

2 points
A constant current is flowing through a capacitor in the direction as indicated in the figure. In going from A to B through the capacitor, we again measure the integral as mentioned above. What do we find?

☐ a positive value
☐ a negative value
☐ zero
■ we do not have enough information to answer



1 point
Would there be a difference in the result between going from A to B through the capacitor or through the air?

■ no difference
☐ yes, there is a difference

2 points
A current is flowing through an "ideal" self-inductor (i.e., the wire is made of super-conducting material) in the direction as indicated in the figure, and this current is *increasing*. In going through the wire of the inductor from A to B, we measure the integral as mentioned above. What do we find?

☐ a positive value
☐ a negative value
■ zero
☐ we do not have enough information to answer

2 points
Would there be a difference in the result between going from A to B through the wire of the self-inductor or through the air?

☐ no difference
■ yes, there is a difference

Faraday's Law states

$$\oint \vec{E} \cdot d\vec{l} = -\frac{d\phi_B}{dt}$$

Resistor

The $\int_A^B \vec{E} \cdot d\vec{l} = IR$ which is positive.

In any closed loop $A \to air \to B \to A$ (here, $B \to A$ is through the resistor), there is no changing magnetic flux going through any surface attached to that closed loop as the current is constant. Thus, the closed loop integral is zero, and consequently $\int_A^B \vec{E} \cdot d\vec{l}$ through the air is again IR (there is no difference).

Capacitor

The $\int_A^B \vec{E} \cdot d\vec{l}$ is the potential difference over the capacitor. Since we do not know which side of the capacitor is positively charged, we do not have enough information.

In any closed loop $A \to air \to B \to A$ (here, $B \to A$ is through the capacitor), there is no changing magnetic flux going through any surface attached to that closed loop as the current is constant. Thus, the closed loop integral is zero, and consequently $\int_A^B \vec{E} \cdot d\vec{l}$ through the air is the same, even though we do not know what the value is (no difference).

Self-inductor

The $\int_A^B \vec{E} \cdot d\vec{l}$ is ZERO as the E-field in the super-conducting wire is zero.

In any closed loop $A \to air \to B \to A$ (here, $B \to A$ is through the wire of the self-inductor), there is a changing magnetic flux through the surface attached to that closed loop as the current is changing. Thus, the closed loop integral is NOT zero! If you integrate in the direction of the current, $-d\phi_B/dt = -LdI/dt$. Thus, if you integrate in the opposite direction, the closed loop integral will be $+LdI/dt$. Thus, in going through the air from $A \to B$ you will find that $\int_A^B \vec{E} \cdot d\vec{l} = +LdI/dt$ as the integral through the self-inductor from B to A is zero.

NOTICE: In going from A to B through the wire of the self-inductor, we will find ZERO; in going through the air we will find a positive value. The E-field is non-conservative, thus the integral DEPENDS ON THE PATH! Some authors call $\int_A^B \vec{E} \cdot d\vec{l}$ the "potential difference" between A and B. That is fine for the resistor and the capacitor as there the E-fields are conservative; the value is independent of the path. However, for a self-inductor the integral depends on the path. Thus "potential difference" defined that way is ill-defined. If you go from A back to A along the following path $A \to air \to B \to A \to air \to B \to A$ (here $B \to A$ is through the wire), you will find $+2LdI/dt$, and if you go N times around, you will find $+NLdI/dt$. If you go from A to A looping around N times in the case of the resistor or the capacitor, you will always find zero no matter what N is.
If you want to understand this difficult issue better, read the Lecture Notes of my 8.02 Lecture #16 (Spring 2002). You can find them on OCW. The title is: "Non-conservative Fields - Do Not Trust Your Intuition".