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# Partial EMF measurement

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Faraday's law gives EMF as the voltage measured across the 2 terminals (A and D in Figure 1) of a loop under the induction of a varying magnetic field. Partial voltage between 2 intermediate points in the loop does exist, but is impossible to measure with a voltmeter. In Figure 1, a voltmeter connected to two arbitrary points B and C, will read the voltage induced by the magnetic field passing through the surface in grey. If the surface is reduced to zero, the voltmeter would read 0. This is why no study of partial voltage exists until now. I propose here an experiment to measure the partial voltage.

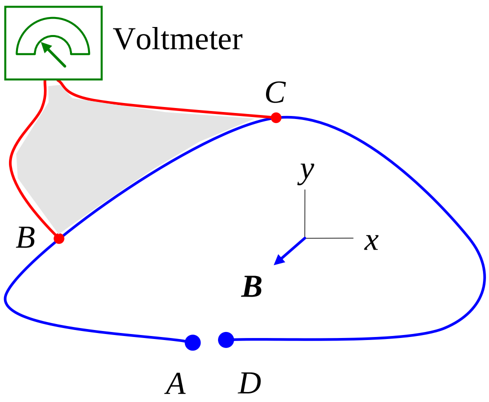
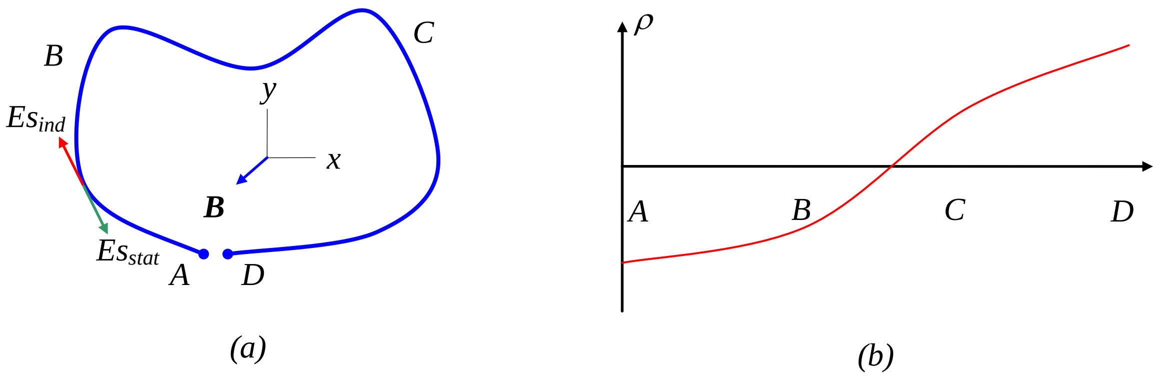



**Figure 1**

1) Method of measurement

The conductor loop ABCD of arbitrary shape in Figure 2 (a) is under the induction of a steadily varying magnetic field ***B***. After a short period of relaxation where the free electrons move in the conductor pushed by the induced electric field $\mathbf{E}_{ind}$, the conductor reaches equilibrium where the electrons stand still and form an uneven distribution of charge. This distribution builds an electrostatic field $\mathbf{E}_{stat}$, which cancels the induced electric field $\mathbf{E}_{ind}$:

$$\mathbf{E}_{stat} = -\mathbf{E}_{ind} \qquad (1)$$




(a) (b)

**Figure 2**

See the discussions about the equilibrium here:
https://groups.google.com/d/topic/sci.physics.electromag/su7Jfa9yNEQ/discussion
https://groups.google.com/d/topic/sci.physics.foundations/RJZ-3aRTDRw/discussion

The electric field's component in the direction of the wire is denoted Es. Within a thin wire, the field created by the net charge distribution is $Es_{stat}$, and that induced by the magnetic field is $Es_{ind}$. At equilibrium $Es_{stat}$ and $Es_{ind}$ oppose exactly to each other (see Figure 2 (a)):

$$Es_{stat} = -Es_{ind} \tag{2}$$

ρ denote the linear density of net charge in the wire; Figure 2 (b) shows a symbolic distribution of ρ along the wire.

As $Es_{stat}$ opposes exactly $Es_{ind}$ everywhere in the wire, the measurement of the electrostatic field will give the induced electric field. There are two ways to measure the electrostatic field. The first is to congeal the distribution of charge during induction and measure $Es_{stat}$ after the magnetic field is suppressed. The second is to measure the distribution of charge in the presence of magnetic field, then compute the electrostatic field.

2) Static measurement

The congealment of charge consists of preventing the free electrons to move when the magnetic field is removed. This can be realized by breaking up the wire into multiple segments during induction. In practice, the wire is constituted by a series of conductor segments connected to each other through removable contacts. Once electric equilibrium is reached, the contacts are removed; the charges are retained in the segments. After that, the magnetic field is removed and the electrostatic field measured. The electrostatic field created by the charged segments will be approximately the same to that during induction.

The greater the number of segments is, the better the similarity of the two electrostatic fields. Figure 3 (a) shows the loop of Figure 2 (a) cut into 21 segments. Figure 3 (b) shows the congealed charges in the segments.

The electrostatic field can be measured with a static field meter in the gaps between 2 segments. One also can measure the charges in all segments and compute the global electrostatic field resulted from these charges.

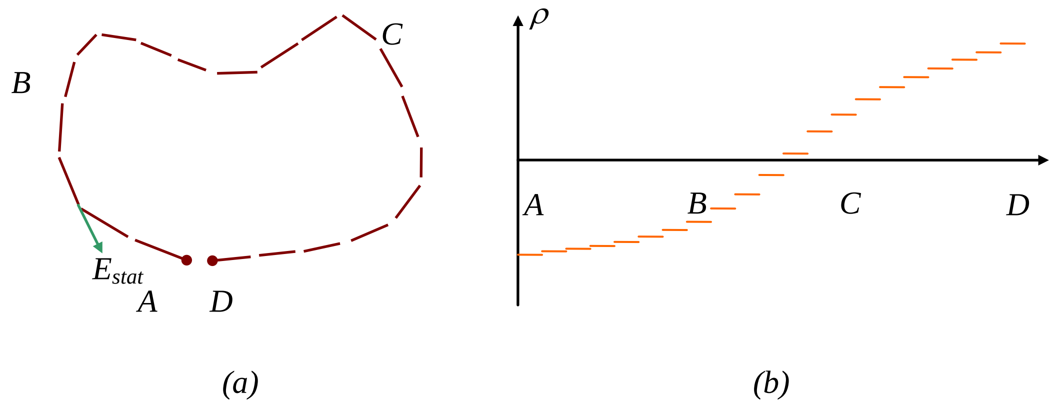



**Figure 3**

As an example, Figure 4 shows a hexagonal loop with the contacts located at the summits, which are fixed on an insulator ring. At the equilibrium, the ring is removed with the contacts on it; the charges retained in the segments are $Q_1$, $Q_2$, $Q_3$, $Q_4$, $Q_5$, and $Q_6$; the magnetic field is then reduced to zero. At the terminals, the capacitor stores the final voltage of EMF. The electrostatic field will be measured at the summits; the charges of all segments will be measured and the global electrostatic field computed.

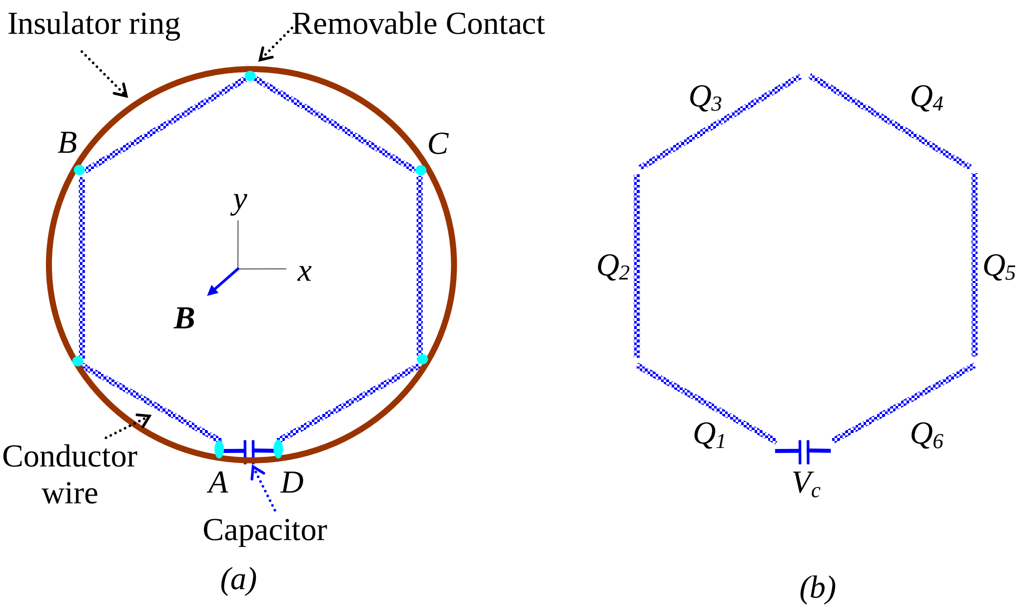



**Figure 4**

3) Dynamic measurement

Static measurement cannot measure loops with changing shape, but general law must fit all possible shape. For loops of any shape, we measure the currents that flow between the segments and compute the charge staying in the segments by integration. Figure 5 shows the hexagonal loop with ammeters located at the summits.

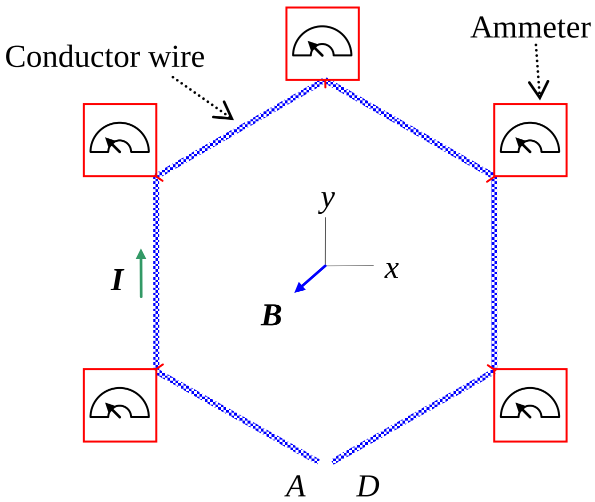



**Figure 5**

The increase rate of a segment's charge is the difference of entering current $I_2$ and the leaving current $I_1$. Then the quantity of charge in that segment is the time integral of $I_2$ -$I_1$ from the moment where the charge in the segment is zero:

$$Q(t) = \int_0^t (I_2 - I_1)dt \tag{3}$$

So, by integrating the differences of currents we obtain the quantity of charge at instant $t$. For current varying sufficiently slowly, there is equilibrium at any moment, the charges in all segments and the global electrostatic field can be computed at any moment.

4) Comments

For a circular loop in uniform magnetic field, the partial voltage should be a linear function of the length from the point A. For loop of arbitrary form, in non uniform magnetic field, only experiment can tell what will be the function of partial voltage and this measurement will be precious to understand the phenomenon of magnetic induction.

Never partial voltage of induced electric field was measured in history. This is a breakthrough experiment that will have important consequences. While dynamic measurement would provide better result by getting an instant image of the changing induced electric field, static measurement is simpler to implement and will give a fixed image of the field. This is particularly suitable to laboratories with limited budget or in search for quick result.

Because of the great interest of this experiment, I think it is better to announce the result as early as possible once obtained, through press release or even TV news if possible; publications in peer-reviewed journals will follow after the date of discovery and the name of its author have publicly been stated. For experimenters in developing country, the success of this experiment can be a mater of national pride and you could become a national hero overnight.

For more information concerning this experiment, please read:

- "Crux of the controversy about Faraday's law" http://pengkuanem.blogspot.com/2012/10/crux-of-controversy-about-faradays-law.html,
- "Faraday's Law Paradox" http://pengkuanem.blogspot.com/2012/10/faradays-law-paradox.html ,
- "Can EMF distribution be known?" http://pengkuanem.blogspot.com/2012/10/can-emf-distribution-be-known.html