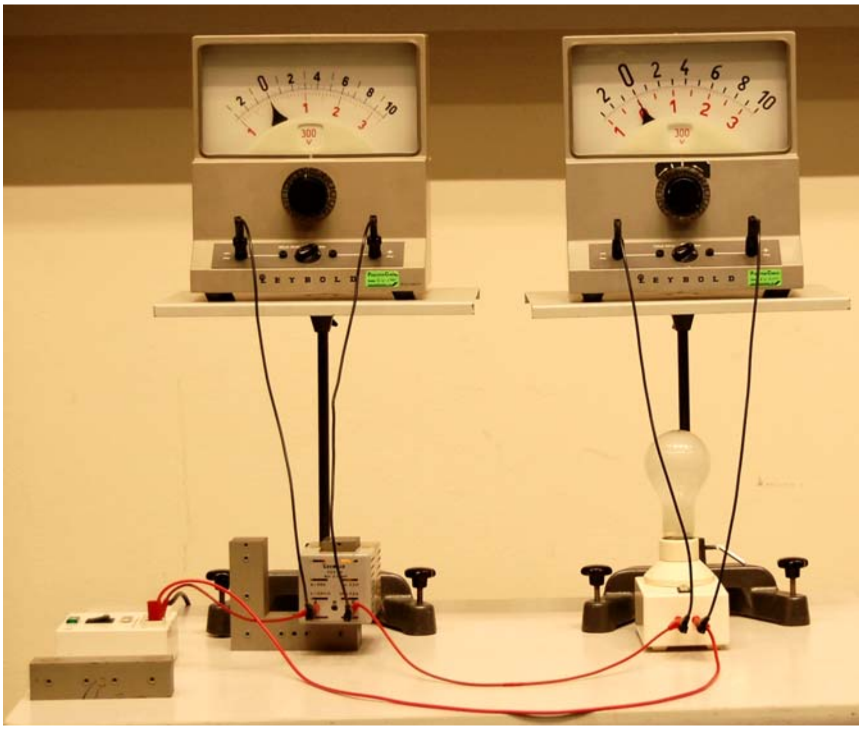
Self-inductance in AC-circuit

Aim: To show how alternating current depends on the value of self-inductance.

Subjects: 5J10 (Self Inductance)
5L20 (LCR Circuits – AC)

Diagram:



Equipment:

- Lamp, 220V/200W.
- Coil, n=500; R=2.5Ω.
- U-core with bar.
- 2 Demonstration meters.
- Safety connection box (Leybold 50206).
- Measuring junction box (Leybold 50205. See Figure 4).
- Net-adapter for mobile telephone (or other appliance).

Safety:

- It's a circuit connected to mains voltage (220V/50Hz). That's why we use a safety connection box. This box shows a **green light** when the mains is disconnected and a **red light** when the mains is connected.

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Presentation: The circuit is build as shown in Figure 1 and in Diagram. First we show the circuit set-up to the students and then connect the two Voltmeters.

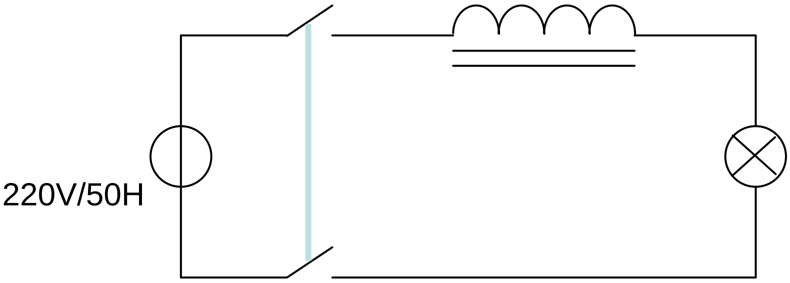

Figure 1

1. Connecting the 220V to the circuit makes the lamp glows strongly (see Figure 2A). The Voltmeter connected to the lamp reads almost 220V: All voltage appears across the lamp; just a very little voltage is read across the coil.
Conclusion is that only a very small emf of self-inductance is generated in the coil.
2. The bar is partly shifted on to the U-core. As soon as the bar touches the second leg of the U-core the lamp dims (see figure 2B). the Voltmeter across the lamp shows a lower voltage now and at the same time we observe an increase in voltage across the coil.
Conclusion is that there is now a higher emf of self-inductance that opposes the 220V.

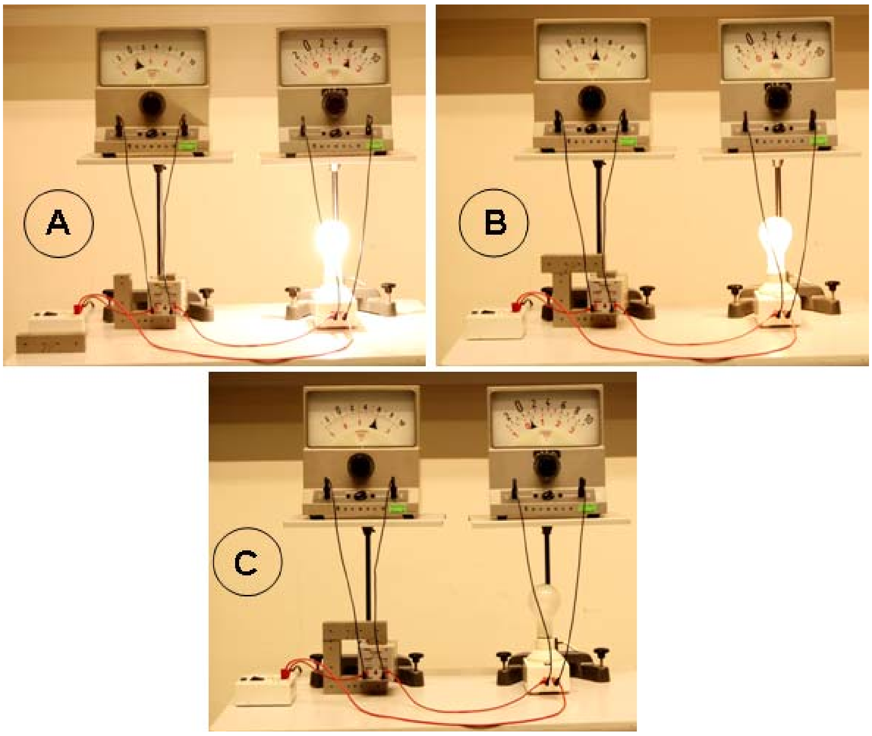

Figure 2

3. When the bar is shifted completely on to the U-core, the lamp only glows very faintly. The voltage read across it is very low. The voltage across the coil is almost 220V now!
Conclusion is that the emf of self-inductance generated in the coil is almost 220V now. Shifting the bar back and forth across the U-core makes the lamp dim less or more.
4. Finally we disconnect the lamp. Now only the self-inductance is connected to the 220V (see Figure 3).

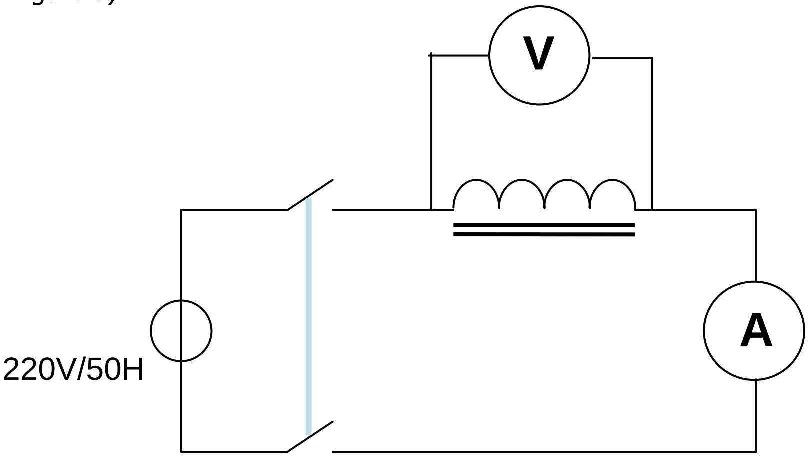

Figure 3

Now the effect of self-inductance is most clear: the voltmeter reads 220V across the coil, and only a small current is flowing (we measure 0.4A). When there would be no self-inductance, the current would be 220V/2.5Ω=88A!
Conclusion is that the emf of self-inductance really opposes the applied voltage.
5. The same demonstration is performed with a commercial net-adapter (used as charger for a mobile telephone; see Figure 4). Here also only the primary coil of the adapter is connected to the mains. We read a current of only 0.3mA!

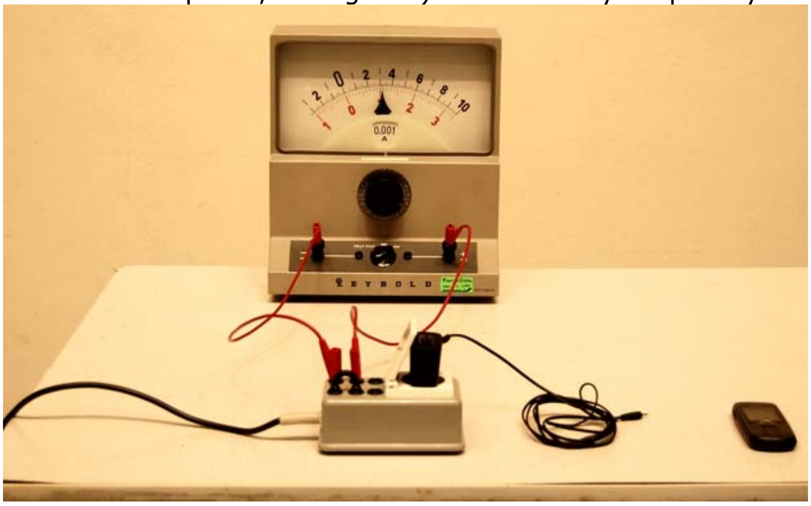

Figure 4

Self-inductance in AC-circuit

Explanation:

The emf induced in a coil is, from Faraday's law: $\mathrm{E} = -N\frac{d\Phi_B}{dt} = -L\frac{dI}{dt}$; L being the coefficient of self-inductance. For a solenoid with a core (μ_r)this is:

$L = \frac{\mu_r\mu_0 N^2 A}{l}$ $L = \frac{\mu_r\mu_0 N^2 A}{l}$. This shows that the higher L, the higher the emf of self-inductance. Shifting the bar across the core changes L, and so the induced emf.

Remarks:

- The core on the bar makes a lot of noise. This is a 100Hz mains hum due to the mains frequency (50Hz).
- The effect of self-inductance can also be translated into impedance of the circuit. In our demonstration **4.** the circuit shows an impedance of 220V/0.4A=550Ω instead of the 2.5Ω of the copper coil.
- In figure B we read $V_{coil} = 130V$ and $V_{lamp} = 110V$. Students easily read this as a total of 240V, so higher than the applied 220V. Phase-shift between these two voltages is responsible for that. The situation must be something like Figure 5 below shows.

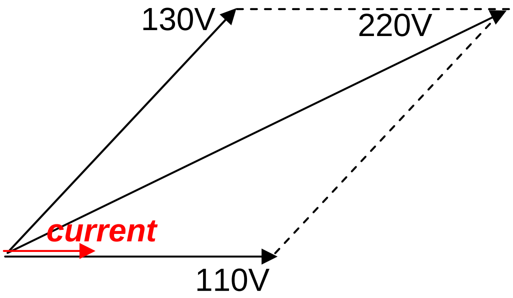

Figure 5

Sources:

- Giancoli, D.G., Physics for scientists and engineers with modern physics, pag. 758-759 and 773-774.
- Wolfson, R., Essential University Physics, pag. 474-477 and 491-492.

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