Physics Course - Exercises Summer 2009

Stefan Kremer (kremer@tkm.uni-karlsruhe.de)
Holger Schmidt (hschmidt@tkm.uni-karlsruhe.de)

Sheet 10
30.9.2009

---

1. Exercise: The tuned circuit

A capacitor with $C = 2\,\mu\text{F}$ is put in series to an inductor with $L = 6\,\mu\text{H}$ and a resistor with $R = 1\,\Omega$.

(i) Draw the circuit.

(ii) What kind of functional behaviour will perform the current?

(iii) Calculate the (possible) period of the oscillation?

(iv) When will the current I_0 possesses its maximum value and how large is it, if initially the current vanishes and the capacitor is charged by $Q_0 = 2\,\mu\text{C}$?

(v) Determine the power $P_R(t)$ which is dissipated in the resistor.

2. Exercise: A capacitor as battery

A charged parallel plate capacitor with area $A = 50\,\text{cm}^2$, distance $d = 1\,\mu\text{m}$ and a material with $\epsilon_r = 40$ between the plates is used as voltage source for two parallel connected resistors with resistances $R_1 = 1.5\,\text{k}\Omega$ and $R_2 = 3\,\text{k}\Omega$. Initially the capacitor should deliver a voltage of $U_0 = 3\,\text{V}$.

(i) Draw the circuit.

(ii) Which resistance enters in the time dependent part of the current?

(iii) Calculate the time constant τ.

(iv) What charge Q_0 has to be placed on the capacitor in order to get the initial voltage?

(v) State the initial current $I_{2,0}$ through R_2.

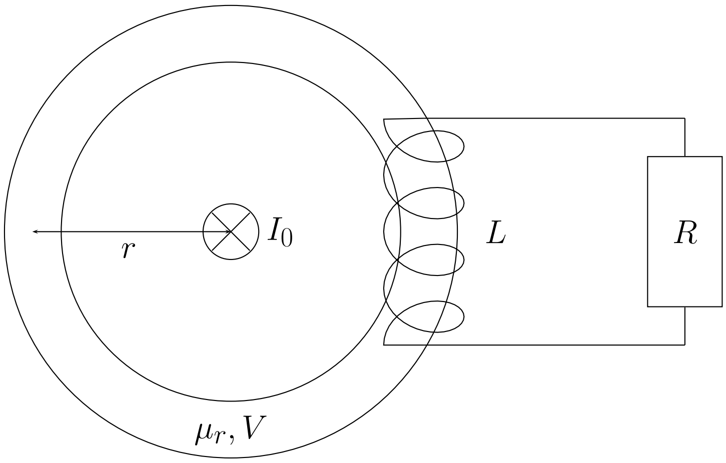
(vi) What is the charge on the capacitor after $t_4 = 4\,\text{ms}$?

(vii) How long does the current at R_2 stay larger than $I_c = 0.1\,\text{mA}$?

3. Exercise: Residual-current device

Background: Residual-current devices are nowadays used in every household. They provide a recoverable and easy to use safety unit for the customers. Such devices consists of a ferromagnetic ring with the power wire on its axis, to enhance its magnetic field. Around the ring a coil is constructed to get a response if the magnetic field collapses or increases rapidly. The resulting current triggers a relay which disconnects the power wire.

We model the relay as a resistor with $R = 15\,\Omega$ and the connected coil around the ring should have a self inductance of $L = 5\,\text{mH}$. At $t = 0\,\text{s}$ the former current in the power wire of $I_0 = 1\,\text{A}$ is collapsing instantaneous. Take a relative permeability of $\mu_r = 1000$ for the ferromagnetic ring with radius $r = 10\,\text{cm}$ and volume $V = 100\,\text{cm}^3$ centred around the power wire.



(i) Determine the magnetic field B_0 at the position of the coil.

(ii) Calculate the time when the current has decayed to half of its former value $\hat{I}$.

(iii) When does it reach the value $\frac{\hat{I}}{\text{e}}$?

(iv) How much energy is dissipated in the resistor depending on the initial current $\hat{I}$?

(v) What is the magnetic energy stored in the coil related to the current and its self inductance?

(vi) Use the formulas which connect the magnetic field and the self-induction to the geometric quantities of the filled coil to derive a formula stating how the energy stored in the coil is related to the magnetic field inside.

(vii) Calculate from it the initial current $\hat{I}$ at the relay and the dissipated energy assuming that at $t = 0\,\text{s}$ all the magnetic energy is stored in the ferromagnetic ring.

Note:

- Permittivity of free space: $\epsilon_0 = 8.85 \cdot 10^{-12}\,\frac{\text{C}}{\text{Vm}}$
- Permeability of vacuum: $\mu_0 = 1.26 \cdot 10^{-6}\,\frac{\text{Vs}}{\text{Am}}$