Musterlösung der Semestrale
"Experimentalphysik II"
Sommersemester 2003

1) a)

(1 → 2) und (3 → 4) sind adiabatische Vorgänge ⇒ $Q = 0$.

(2 → 3) aufgenommene Wärme

$$|Q_{23}| = |C_v(T_3 - T_2)| \; ; \; Q_{23} > 0$$

(4 → 1) abgegebene Wärme

$$|Q_{41}| = |C_v(T_1 - T_4)| \; ; \; Q_{41} < 0$$

Wirkungsgrad: $\eta = 1 - \frac{|Q_{41}|}{|Q_{23}|} = 1 - \frac{|T_4 - T_1|}{|T_3 - T_2|}$

1b) Adiabatengleichung

$$T_3 V_2^{\gamma-1} = T_4 V_1^{\gamma-1} \quad \text{und} \quad T_2 V_2^{\gamma-1} = T_1 V_1^{\gamma-1}$$

$$\Rightarrow \frac{T_3}{T_4} = \frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} \quad \text{und} \quad \frac{T_2}{T_3} = \frac{T_1}{T_4}$$

Damit folgt für den Wirkungsgrad

$$\eta = 1 - \frac{T_4 - T_1}{T_3 - T_2} = 1 - \frac{1 - T_1/T_4}{1 - T_2/T_3} \cdot \frac{T_4}{T_3}$$

$$= 1 - \frac{T_4}{T_3} = 1 - \left(\frac{V_2}{V_1}\right)^{\gamma-1}$$

c) $\eta = 1 - \left(\frac{V_2}{V_1}\right)^{\gamma-1} = 1 - \left(\frac{1}{6}\right)^{0{,}3} = 0{,}415$

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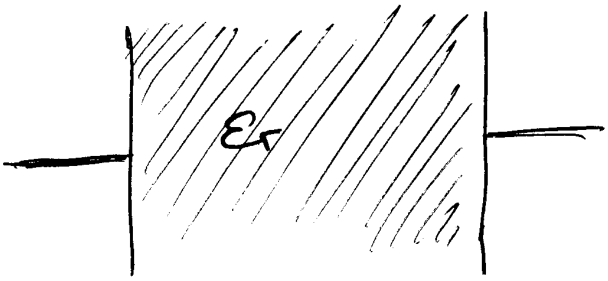
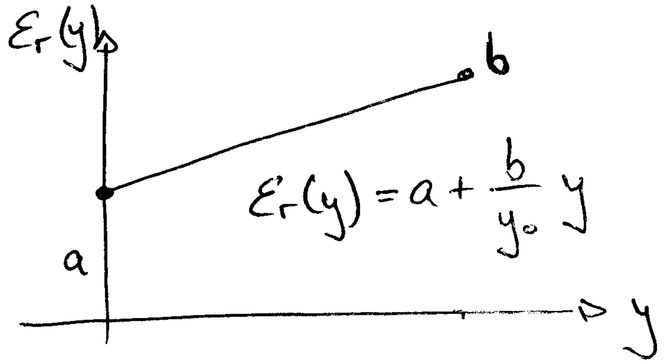
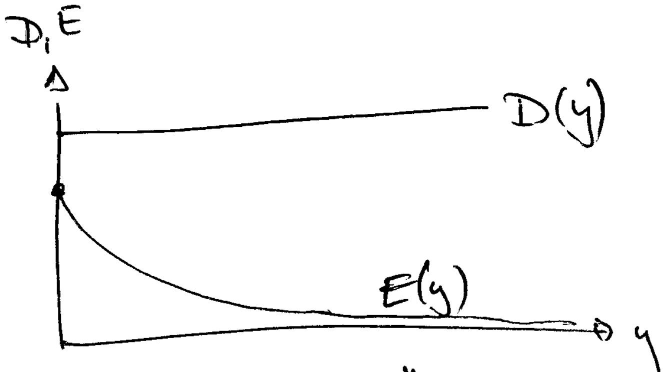




a) $$D = \frac{Q}{A} = \text{const.}$$

$$E(y) = \frac{D}{\varepsilon_0 \varepsilon_r} = \frac{Q}{\varepsilon_0 \varepsilon_r A} = \frac{Q}{A \cdot \varepsilon_0 \left(a + \frac{b}{y_0} \cdot y\right)}$$

b)



c) $$U = \int_0^{y_0} E \, d\tilde{y} = \int_0^{y_0} \frac{Q}{A\varepsilon_0} \frac{1}{a + \frac{b}{y_0}\tilde{y}} \, dy = \left[\frac{Q y_0}{A \varepsilon_0 b} \ln\left(a + \frac{b}{y_0}\tilde{y}\right) \right]_0^{y_0}$$

$$= \frac{Q y_0}{A \varepsilon_0 b} \ln\left(\frac{a+b}{a}\right)$$

d) $$C = \frac{Q}{U} = \frac{A \varepsilon_0 b}{y_0 \cdot \ln\left(\frac{a+b}{a}\right)}$$

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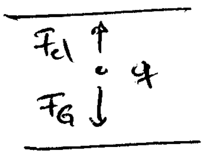
3)



$$F_G = m \cdot g$$

$$F_{el} = q \cdot E = q \cdot \frac{U}{d} = q \cdot \frac{1}{d} \cdot \frac{Q}{C} = q \cdot \frac{1}{d} \cdot \frac{Q}{\frac{\varepsilon_0 A}{d}}$$

$$= q \cdot \frac{Q}{\varepsilon_0 A}$$

Schwebendes Tröpfchen:

$$F_G = F_{el}$$

$$m \cdot g = q \cdot \frac{Q}{\varepsilon_0 A}$$

$$\Rightarrow Q = \frac{m \cdot g \cdot \varepsilon_0 A}{q}$$

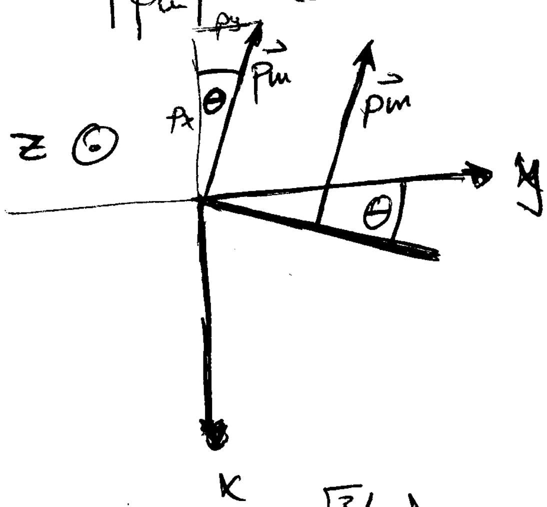
4) a) $|\vec{p}_m| = I \cdot A = 1A \cdot 0{,}11 \cdot 0{,}14 m^2 = 1{,}54 \cdot 10^{-2} Am^2$

Richtung:

$\vec{z}$ - Komponente $= 0$

$\vec{y}$ - Komponente: $+|\vec{p}_m| \cdot \sin\Theta$

$\vec{x}$ - Komponente: $-|\vec{p}_m| \cdot \cos\Theta$



$$\Rightarrow \quad \vec{p}_m = 1{,}54 \cdot 10^{-2} Am^2 \cdot \begin{pmatrix} -\sqrt{3}/2 \\ 1/2 \\ 0 \end{pmatrix}$$

b) $E_{pot} = -\vec{p}_m \cdot \vec{B}$ mit $\vec{B} = 1T \cdot \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}$

$$= 1{,}54 \cdot 10^{-2} Am^2 \, \frac{\sqrt{3}}{2} \cdot 1 \, \frac{Vs}{m^2} = 1{,}33 \cdot 10^{-2} J$$

$$\vec{M} = \vec{p}_m \times \vec{B} = 1{,}54 \cdot 10^{-2} Am^2 T \begin{pmatrix} -\sqrt{3}/2 \\ 1/2 \\ 0 \end{pmatrix} \times \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}$$

$$= \begin{pmatrix} 0 \\ 0 \\ -\frac{1}{2} \end{pmatrix} \cdot 1{,}54 \cdot 10^{-2} J$$

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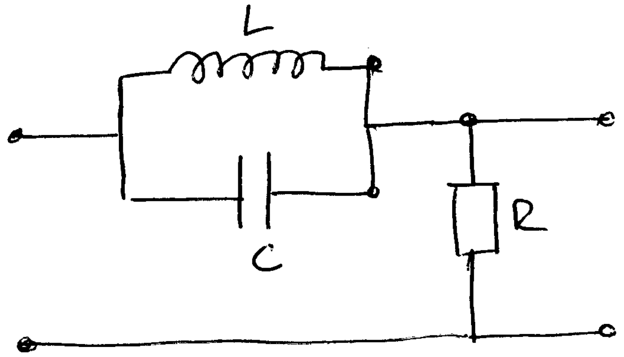
5) im Fernfeld "sieht" man eine Punktladung mit Ladung Q

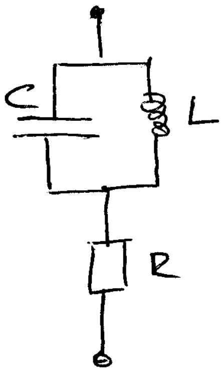
$$\Rightarrow |\vec{E}(r)| = \frac{Q}{4\pi\varepsilon_0}\frac{1}{r^2}|\vec{e}_r|$$

$$\phi(r) = \frac{Q}{4\pi\varepsilon_0}\frac{1}{r}$$

6)



äquivalente Schaltung:



a) L und C parallel: $\frac{1}{Z_p} = \frac{1}{i\omega L} + i\omega C$

$$\frac{1}{Z_p} = \frac{-i + i\omega^2 LC}{\omega L} = i\left(\frac{1}{\omega L}(\omega^2 LC - 1)\right)$$

$$Z_{gesamt} = R + Z_p = R + \frac{\omega L}{i(\omega^2 LC - 1)} = R - i\frac{\omega L}{\omega^2 LC - 1}$$

6 b) Spannungsteiler:

$$\frac{U_{out}}{U_{in}} = \frac{R}{Z_{gesamt}} = \frac{R}{R - i\,\frac{\omega L}{\omega^2 LC - 1}}$$

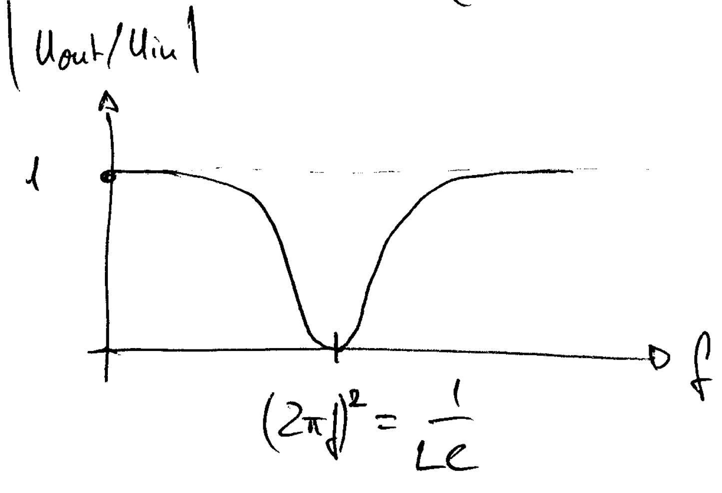
$$= \frac{R\left(R + i\,\frac{\omega L}{\omega^2 LC - 1}\right)}{R^2 + \frac{\omega^2 L^2}{(\omega^2 LC - 1)^2}}$$

$$= \left\{\frac{R}{R^2 + \frac{\omega^2 L^2}{(\omega^2 LC - 1)^2}}\right\} \cdot \left(R + i\,\frac{\omega L}{\omega^2 LC - 1}\right)$$

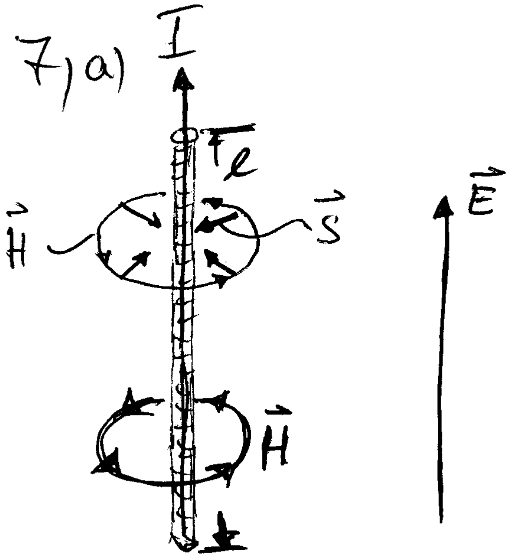
$$\left|\frac{U_{out}}{U_{in}}\right| = \frac{R}{R^2 + \frac{\omega^2 L^2}{(\omega^2 LC - 1)^2}} \cdot \left(R^2 + \frac{\omega^2 L^2}{(\omega^2 LC - 1)^2}\right)^{1/2}$$

$$= \frac{R}{\sqrt{R^2 + \frac{\omega^2 L^2}{(\omega^2 LC - 1)^2}}}$$

c)



7) a)



$$\vec{S} = \vec{E} \times \vec{H}$$

$\vec{E}$ entlang des Drahtes (sonst kein Stromfluß)

$\vec{S}$ radial nach innen hin zu dem Draht

b) $|\vec{S}| = E \cdot H$ $\qquad E = \frac{U}{\ell}$ und $H = \frac{I}{2\pi r}$

$$|\vec{S}| = \frac{U \cdot I}{2\pi r \ell} = \frac{\text{elektrische Leistung}}{\text{Zylinderoberfläche des Drahtes}}$$