Name:

Total points: **of** 34

Total score: **%**

JUAS 2013 RF Engineering — Exam

Useful Numbers and Relations

c = $\lambda \cdot f$
c = $3 \cdot 10^8$ m/s
$\epsilon = \epsilon_0 \cdot \epsilon_r$
$\epsilon_0 = 8.85 \cdot 10^{-12}$ As/Vm
$\mu = \mu_0 \cdot \mu_r$
$\mu_0 = 4\pi \cdot 10^{-7}$ Vs/Am

Question 1

A copper cavity of the pillbox type has a height h = 15 cm and a diameter d = 2a = 25 cm. It resonates at f_{res} = 1.2 GHz (NOT the E_{010} mode). This cavity shall be scaled to a resonance frequency of f_{res} = 500 MHz. (copper: $\sigma_{copper} = 58 \cdot 10^6$ S/m, $\mu_r = 1$)

1. What are the dimensions of the new cavity?
2. What is the excited mode in this cavity for this frequency?

Question 2

The scaled cavity from question 1 will now be operated at the E_{010} mode.

1. What is the resonance frequency for this mode? Will it be possible to operate the cavity on this mode without danger of parasitic modes?
2. Determine the Q value, R/Q as well as the lumped elements R, L, C of the equivalent circuit.
3. The cavity is driven by a 50 kW_{RMS} transmitter (50 Ω) at critical coupling. Determine the gap voltage. What is the transformer ratio the coupler has to cover? Is Kilpatrick voltage breakdown an issue for this cavity when operated in vacuum?
4. What would be the Q value and the gap Voltage for the same cavity made of steel (steel: $\sigma_{StSt} = 1.4 \cdot 10^6$ S/m, $\mu_r = 10$)?
5. To improve the Q value of such a steel cavity, it is silver-coated on the inside. Determine the requred coating thickness to assure that 99% (5 δ) of the surface currents flow in the silver layer (silver: $\sigma_{silver} = 63 \cdot 10^6$ S/m, $\mu_r = 1$).

Bonus question: What is the ratio of number of turns for the transformer in the equivalent circuit of the cavity when powered by the 50 Ω transmitter?

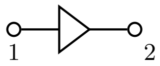
Question 3

Two coaxial cables are connected — one with a characteristic impedance of $Z_1 = 10\,\Omega$ and the other with $Z_2 = 50\,\Omega$. Determine the S-parameters and the voltage transmission coefficient for this step in characteristic impedance seen from the $50\,\Omega$ cable.

S_{11} =	S_{12} =
S_{21} =	S_{22} =
t =	

Question 4

1. The S-matritx of an ideal amplifier is given as



$$S = \begin{bmatrix} 0 & 0 \\ 50 & 0 \end{bmatrix}$$

   What is the gain of the amplifier in dB?

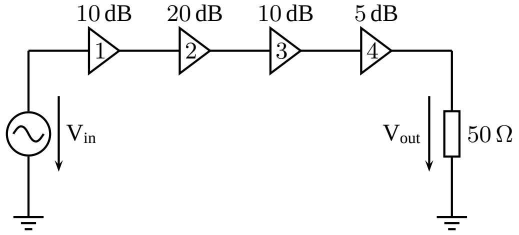
   G =

2. Write down the S-matrix of an ideal attenuator with $16\,\mathrm{dB}$ attenuation.

3. How does the S-matirx of a transmission line ($50\,\Omega$) of length $\frac{7\lambda}{8}$ look like?

Question 5

Imagine an amplifier chain:



1. What would be the input voltage V_{in} (RMS) to obtain $100\,\mathrm{kW_{RMS}}$ in the load?
2. What are the power levels at the output of each individual amplifier?

Amplifier	power level at output
1	
2	
3	
4	

Question 6

1. Fill in the table below for the points P_1 to P_5 marked in the Smith chart — the chart is normalized to $50\,\Omega$.

$\mathbf{P_x}$	$\Gamma(\mathbf{z})$ [mag, phase]	**z** [Re(z), Im(z)]	**Z** [Re(z), Im(z)]	**y** [Re(y), Im(y)]
P_1				
P_2				
P_3				
P_4				
P_5				

2. Mark the points P_6 to P_{10} in the chart.

P_6	z = 3 + 4j
P_7	Z = (75 - 90j) Ω
P_8	$\lvert\Gamma\rvert = 0.5$, arg(Γ) = $45°$
P_9	Z = $50\,\Omega$
P_{10}	$\lvert\Gamma\rvert = 0.2$, arg(Γ) = $-106°$

Bonus question: Mark the Impedance of a parallel RLC circuit with R = $75\,\Omega$, L = $60\,$nH and C = $40\,$pF at $500\,$MHz in the Smith chart. To this circuit, a transmission line of length $\frac{\lambda}{20}$ is connected. Mark its locus of impedance in the chart. What is the resulting Impedance?

The Complete Smith Chart

Black Magic Design