JUAS 2012 – Exam

$\mu = \mu_0 \, \mu_r$
$\mu_0 = 4\pi \cdot 10^{-7}$ Vs/(Am)
$c = 3 \cdot 10^8$ m/s

Name: ____________________   Points: ______ of 20

1 Transmission lines (2 points)

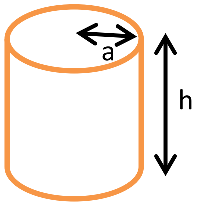
A TEM transmission line has a characteristic impedance of $\mathbf{Z_C = 75\ \Omega}$ and a velocity of propagation of $\mathbf{v = 0.5 \cdot c}$ ($c = 3 \cdot 10^8$ m/s, $\mu_r = 1$)

1.) What is the capacitance **C'** and inductance **L'** per unit length? (0.5 Points)

2.) What is the relative permittivity $\boldsymbol{\varepsilon_r}$ of the dielectric? (0.5 Points)

3.) The transmission line with the above parameters is realized as a coaxial structure. The outer radius is **R = 10 mm**. What is the inner radius **r**? (1 Point)

2 Cavities (8 points)



Design a pillbox cavity. The $E_{010} = TM_{010}$ mode shall resonate at $f_{res} = 2.95$ GHz. The aspect ratio shall be $a/h = 0.5$.

1. What is the radius *a* of the cavity? (0.5 Points)
2. What is the height *h* of the cavity? (0.5 Points)
3. The 3 dB bandwidth of the unloaded resonance shall be 150 kHz, how big does the unloaded Q_0 of the cavity need to be? (0.5 Points)
4. What is the maximum tolerable surface resistance **σ** of the cavity walls to get $Q_0 = 20\,000$. [$\mu = \mu_0 = 4\pi \cdot 10^{-7}$ Vs/(Am)] (2.5 Points)
5. What is the R/Q for this cavity geometry? (0.5 Points)
6. Derive the equivalent circuit parameters R, L and C for the cavity with $Q_0 = 20\,000$ and $R/Q = 370$ (1.5 Points)
7. The cavity is critically coupled to an RF power amplifier and driven by 50 W of input power on its resonant frequency. The loaded Q_L is 10 000. What is the stored energy W_{CAV} in the cavity? (1 Point)
8. What is the peak gap voltage V_{gap}? (0.5 Points)
9. Operating the cavity in air, is “Kilpatrick” voltage breakdown a problem? (0.5 Points)

3 S – parameters (2 points)

Match the measured S-parameters in matrix form to the corresponding components.

$$\boldsymbol{S_1} = \frac{1}{\sqrt{2}}\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \qquad \boldsymbol{S_2} = \begin{bmatrix} 0 & -j \\ -j & 0 \end{bmatrix} \qquad \boldsymbol{S_3} = \begin{bmatrix} 0 & 0 \\ 1 & 0 \end{bmatrix} \qquad \boldsymbol{S_4} = \begin{bmatrix} 0 & -1 \\ -1 & 0 \end{bmatrix}$$

Write the names ($\boldsymbol{S_1} - \boldsymbol{S_4}$) in the empty boxes below. (Each correct match = 0.5 points)

Component	Isolator	Transmission line, length = λ/2	Transmission line, length = λ/4	3 dB attenuator
S – Matrix				

4 Smith chart (4 points + 2.5 bonus point)

Given in the table below are several impedances $\mathbf{Z_N}$ or reflection coefficients $\mathbf{\Gamma_N}$, measured at specific frequencies.

They have been normalized already with the characteristic impedance $Z_C = 50\ \Omega$ in the following way: $Z_N = Z/Z_C$

Point no.	**P_1**	**P_2**	**P_3**	**P_4**
Z_N or Γ_N	$\mathbf{Z_N}$ = 1	$\mathbf{Z_N}$ = 0.5 + 0.5j	$\lvert\mathbf{\Gamma_N}\rvert$ = 0.45 arc($\mathbf{\Gamma_N}$) = -117°	$\mathbf{Z_N}$ = 0
f [GHz]	3.000	2.997	3.003	0.01

Point no.	**P_5**	**P_6**	**P_7**	**P_8**
Z_N or Γ_N	$\mathbf{Z_N}$ = 0.2 + 0.4j	$\mathbf{Z_N}$ = 0.2 - 0.4j	$\lvert\mathbf{\Gamma_N}\rvert$ = 1 arc($\mathbf{\Gamma_N}$) = 0°	$\lvert\mathbf{\Gamma_N}\rvert$ = 0.49 arc($\mathbf{\Gamma_N}$) = 52°
f [GHz]	2.994	3.006	-	-

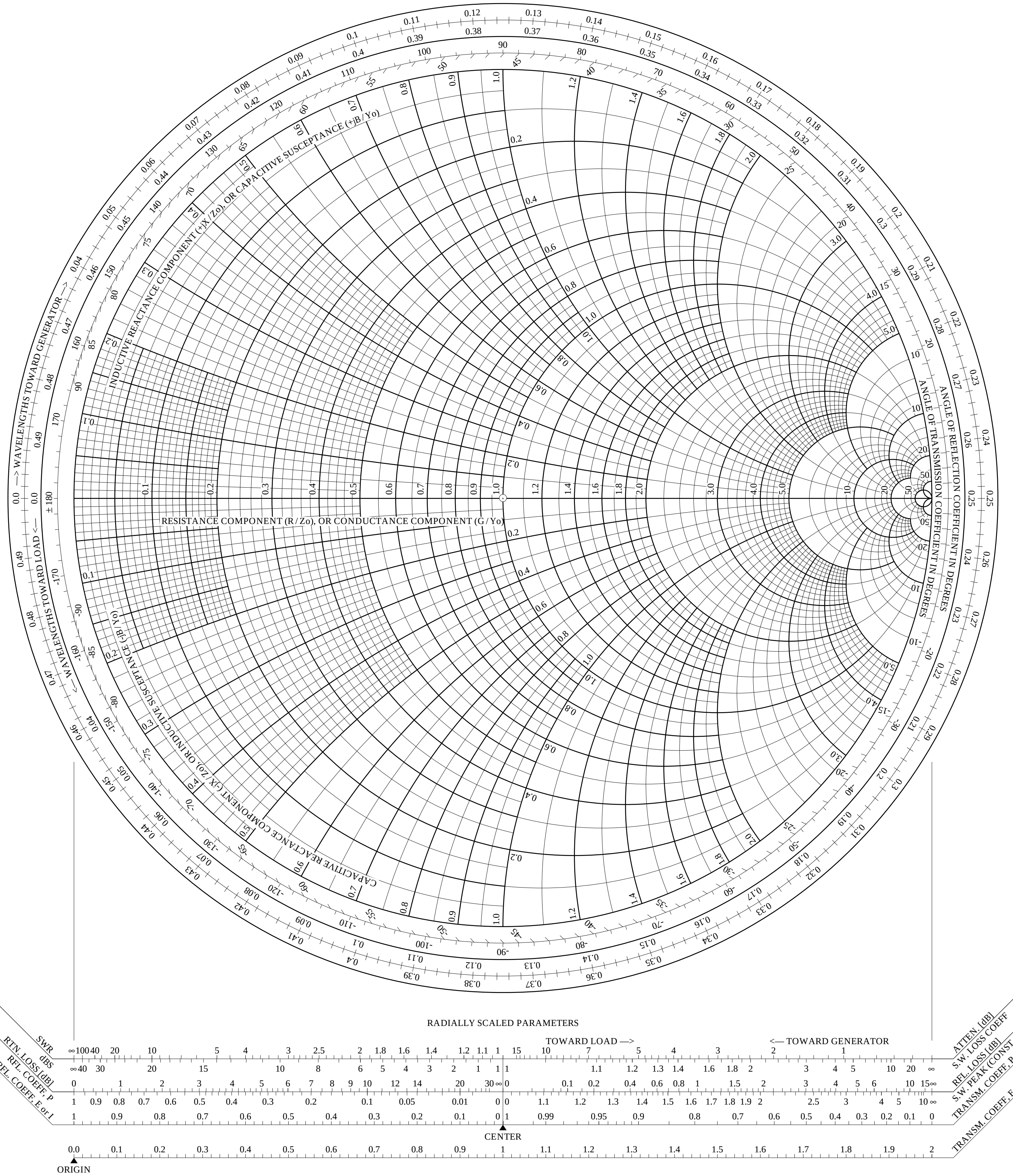
1. Mark all the points in the attached smith chart (including each point no.)
   Use your compass and the rulers at the bottom of the smith chart for the polar coordinates
   (0.5 points for each correctly marked point)

Bonus points (full score can be reached without answering these questions)

1. Design a matching circuit. The point P_2 in the smith chart shall be matched to $Z_C = 50\ \Omega$. Use only **one 50 Ω transmission line** and **one series capacitor.** Draw the solution in the smith chart. Numerical answers are not needed. (1 point)
2. Draw a circle through the points P1 – P6. This is the result of a S_{11} measurement of a microwave cavity with a network analyser.
   What is the resonant frequency f_{res} of the cavity? (Look it up in the table) (0.5 points)
3. What is the unloaded Q_0 of the cavity? (1 point)

The Complete Smith Chart

Black Magic Design



5 Multiple choice (4 points)

Tick the correct answer like this: ☒ . Only one answer is correct. 0.5 points for each question if the correct answer is ticked. 0 points if a wrong or more than one answer is ticked.

1. The R over Q value (R/Q) of a cavity depends on:
   - The geometry of the cavity only
   - The geometry and the material of the cavity walls
   - The material of the cavity walls only
2. The time constant τ of a cavity describes the time it takes for a quantity to decay by the factor 1/e. Which quantity is it?
   - The field in the cavity.
   - The stored energy in the cavity.
   - The resonant frequency of the cavity.
3. For which aspect ratio (h/2a) does the E_{010} mode in a pillbox cavity become degenerated with the H_{111} mode?
   - h/2a = 0.5
   - h/2a = 1
   - h/2a = 1.5
4. If a ferrite is magnetized by a static magnetic bias field H, its effective permeability (μ_r) …
   - decreases
   - stays constant
   - increases
5. For Kilpatrick voltage breakdown, the breakdown voltage is dependent on frequency in the following way …
   - proportional to $\sqrt{f}$
   - proportional to f
   - proportional to f^2
6. Which of these is a TEM transmission lines?
   - Microstripline
   - Homogeneously filled coaxial cable
   - Ferrite filled rectangular waveguide
7. In a simple Klystron, the electron beam goes through two RF cavities. What is the purpose of the first one?
   - To accelerate the beam
   - To modulate the beam in velocity (create bunches)
   - To focus the beam and avoid losses
8. Putting a piece of dielectric material in a cavity (capacitive loading) will:
   - Increase its resonant frequency
   - Decrease its resonant frequency
   - Not change its resonant frequency