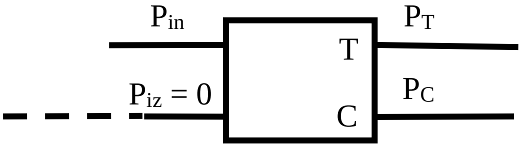
Subject no. 1

1. $z = 1.165 + j \cdot 0.720$; $Y = 1 / 50\Omega / (1.165 + j \cdot 0.720) = 0.0124S + j \cdot (-0.0077)S$; $\Gamma = (z-1)/(z+1) = (1.165 + j \cdot 0.720-1)/(1.165 + j \cdot 0.720+1) = 0.168+j \cdot (0.277) = 0.324\angle 58.7°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.098$, $Z_{0E} = 55.150\Omega$, $Z_{0O} = 45.331\Omega$
b) $P_c = 71.5\mu W = -11.457dBm$; $P_{in} = P_c + C = -11.457dBm + 20.2dB = 8.743dBm = 7.487$ **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 7.487mW – 0.0715mW – 0 = 7.415 **mW** = 8.701 **dBm**



3. The shunt RC load with R = 45Ω and C = 0.364pF has $Z_L = 23.01\Omega + j \cdot (-22.49)\Omega$ at 9.5GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j \cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j \cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j \cdot \tan(\beta l)}{1 + j \cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j \cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2 \cdot \pi \cdot 3/5)=0.727$; $\cot(\beta l)= 1.376$; $Z_{in} = 23.97\Omega\angle 30.2° = 20.72\Omega + j \cdot (12.05)\Omega$;

b) If the line becomes open-circuited $Z_L = \infty$; $Z_{in} = j \cdot (-82.58)\Omega$

4. a) $G = G_1 + G_2 + G_3 = 11dB + 16dB + 10dB = 37dB$
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
$F_1 = 2.75dB=1.884$, $G_1 = 11dB=12.589$, $F_2 = 2.15dB=1.641$, $G_2 = 16dB=39.811$, $F_3 = 2.80dB=1.905$,
$F = 1.884 + (1.641-1)/12.589 + (1.905-1)/12.589/39.811 = 1.936 = 2.870dB$

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

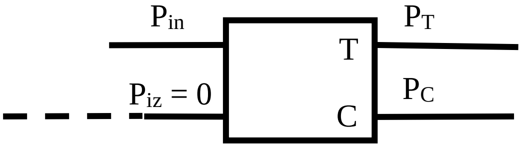
	Δ	|Δ|	K	μ
T1	-0.369+ j·(-0.328)	0.493	0.569	0.446
T2	-0.155+ j·(-0.374)	0.405	0.675	0.735

b) μ (T1) < μ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}| \cdot |S_{12}| \cdot |S_{21}| \cdot |S_{22}| / (1-|S_{11}|^2) / (1-|S_{22}|^2) = 0.316$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 31.484 = 14.981$ dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.308$, $\arg(S_{22}^*) = 96.3°$; $\theta_{S1} = 5.8°$; $\mathrm{Im}(y_S) = -0.647$; **or** $\theta_{S2} = 77.9°$; $\mathrm{Im}(y_S) = 0.647$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.749$, $\arg(S_{11}^*) = 92.0°$; $\theta_{S3} = 23.3°$; $\mathrm{Im}(y_S) = -2.261$; **or** $\theta_{S4} = 64.7°$; $\mathrm{Im}(y_S) = 2.261$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $\mathrm{Im}(y_S) = (-0.647) + (-2.261) = -2.908$; $\theta_{S1} = 5.8°$; $\theta_{P1} = 109.0°$; $\theta_{S3} = 23.3°$; **or**
Solution 2: $\mathrm{Im}(y_S) = (-0.647) + (2.261) = 1.613$; $\theta_{S1} = 5.8°$; $\theta_{P2} = 58.2°$; $\theta_{S4} = 64.7°$; **or**
Solution 3: $\mathrm{Im}(y_S) = (0.647) + (-2.261) = -1.613$; $\theta_{S2} = 77.9°$; $\theta_{P3} = 121.8°$; $\theta_{S3} = 23.3°$; **or**
Solution 4: $\mathrm{Im}(y_S) = (0.647) + (2.261) = 2.908$; $\theta_{S2} = 77.9°$; $\theta_{P4} = 71.0°$; $\theta_{S4} = 64.7°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 2

1. $z = 0.820 + j\cdot1.170$; $Y = 1 / 50\Omega / (0.820 + j\cdot1.170) = 0.0080S + j\cdot(-0.0115)S$; $\Gamma = (z-1)/(z+1) = (0.820 + j\cdot1.170-1)/(0.820 + j\cdot1.170+1) = 0.222+j\cdot(0.500) = 0.547\angle66.0°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.082$, $Z_{0E} = 54.295\Omega$, $Z_{0O} = 46.045\Omega$
b) Pc = 127.0µW = -8.962dBm ; Pin = Pc + C = -8.962dBm + 21.7dB = 12.738dBm = 18.785 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 18.785mW – 0.1270mW – 0 = 18.658 **mW** = 12.709 **dBm**



3. The shunt RC load with R = 30Ω and C = 0.408pF has $Z_L = 21.32\Omega + j\cdot(-13.61)\Omega$ at 8.3GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0\cdot\tan(\beta l)}{Z_0 + j\cdot Z_L\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot\cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot3/6)=0.000$; $\cot(\beta l)= \infty$; $Z_{in} = 25.29\Omega\angle-32.6° = 21.32\Omega + j\cdot(-13.61)\Omega$;

b) If the line becomes short-circuited $Z_L = 0$; $Z_{in} = j\cdot(0.00)\Omega$

4. a) $G = G_1 + G_2 + G_3$ = 13dB + 19dB + 11dB = 43dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.74dB=1.879, G_1 = 13dB=19.953, F_2 = 2.20dB=1.660, G_2 = 19dB=79.433, F_3 = 2.26dB=1.683,
F = 1.879 + (1.660−1)/19.953 + (1.683−1)/19.953/79.433 = 1.913 = 2.817dB

5. a) Must compute either µ or µ' (**as requested!**) (L8/2023, S96 or 97);

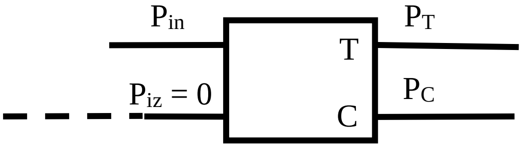
	Δ	|Δ|	K	µ
T1	-0.472+ j·(0.086)	0.479	0.753	0.637
T2	-0.234+ j·(-0.161)	0.284	0.877	0.903

b) µ (T1) < µ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2) = 0.094$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 24.045$ = 13.810 dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.159$, $\arg(S_{22}^*) = 139.6°$; $\theta_{S1} = 159.8°$; $\mathrm{Im}(y_S) = -0.322$; **or** $\theta_{S2} = 60.6°$; $\mathrm{Im}(y_S) = 0.322$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.637$, $\arg(S_{11}^*) = 127.9°$; $\theta_{S3} = 0.8°$; $\mathrm{Im}(y_S) = -1.653$; **or** $\theta_{S4} = 51.3°$; $\mathrm{Im}(y_S) = 1.653$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $\mathrm{Im}(y_S) = (-0.322) + (-1.653) = -1.975$; $\theta_{S1} = 159.8°$; $\theta_{P1} = 116.9°$; $\theta_{S3} = 0.8°$; **or**
Solution 2: $\mathrm{Im}(y_S) = (-0.322) + (1.653) = 1.331$; $\theta_{S1} = 159.8°$; $\theta_{P2} = 53.1°$; $\theta_{S4} = 51.3°$; **or**
Solution 3: $\mathrm{Im}(y_S) = (0.322) + (-1.653) = -1.331$; $\theta_{S2} = 60.6°$; $\theta_{P3} = 126.9°$; $\theta_{S3} = 0.8°$; **or**
Solution 4: $\mathrm{Im}(y_S) = (0.322) + (1.653) = 1.975$; $\theta_{S2} = 60.6°$; $\theta_{P4} = 63.1°$; $\theta_{S4} = 51.3°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 3

1. $z = 1.220 - j\cdot 0.755$; $Y = 1 / 50\Omega / (1.220 - j\cdot 0.755) = 0.0119S + j\cdot(0.0073)S$; $\Gamma = (z-1)/(z+1) = (1.220 - j\cdot 0.755-1)/(1.220 - j\cdot 0.755+1) = 0.192+j\cdot(-0.275) = 0.335\angle -55.0°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.082$, $Z_{0E} = 54.295\Omega$, $Z_{0O} = 46.045\Omega$
b) Pc = 143.5µW = -8.431dBm ; Pin = Pc + C = -8.431dBm + 21.7dB = 13.269dBm = 21.225 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 21.225mW – 0.1435mW – 0 = 21.082 **mW** = 13.239 **dBm**



3. The series RL load with R = 50Ω and L = 0.617nH has $Z_L = 50.00\Omega + j\cdot(32.56)\Omega$ at 8.4GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot \tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 1/3)=-1.732$; $\cot(\beta l)= -0.577$; $Z_{in} = 41.13\Omega\angle -22.5° = 38.00\Omega + j\cdot(-15.74)\Omega$;

b) If the line becomes short-circuited $Z_L = 0$; $Z_{in} = j\cdot(-112.58)\Omega$

4. a) $G = G_1 + G_2 + G_3$ = 17dB + 15dB + 13dB = 45dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.44dB=1.754, G_1 = 17dB=50.119, F_2 = 2.15dB=1.641, G_2 = 15dB=31.623, F_3 = 2.11dB=1.626,
F = 1.754 + (1.641−1)/50.119 + (1.626−1)/50.119/31.623 = 1.767 = 2.473dB

5. a) Must compute either µ or µ' (**as requested!**) (L8/2023, S96 or 97);

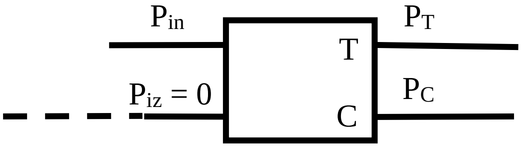
	Δ	|Δ|	K	µ'
T1	-0.477+ j·(0.066)	0.481	0.746	0.808
T2	-0.234+ j·(-0.173)	0.291	0.866	0.936

b) µ' (T1) < µ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2)$ = 0.101 (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}|$ = 24.182 = 13.835 dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.167$, $\arg(S_{22}^*) = 136.1°$; $\theta_{S1} = 161.8°$; $Im(y_S) = -0.339$; **or** $\theta_{S2} = 62.1°$; $Im(y_S) = 0.339$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.640$, $\arg(S_{11}^*) = 126.0°$; $\theta_{S3} = 1.9°$; $Im(y_S) = -1.666$; **or** $\theta_{S4} = 52.1°$; $Im(y_S) = 1.666$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S)$ = (-0.339) + (-1.666) = -2.005; $\theta_{S1} = 161.8°$; $\theta_{P1} = 116.5°$; $\theta_{S3} = 1.9°$; **or**
Solution 2: $Im(y_S)$ = (-0.339) + (1.666) = 1.327; $\theta_{S1} = 161.8°$; $\theta_{P2} = 53.0°$; $\theta_{S4} = 52.1°$; **or**
Solution 3: $Im(y_S)$ = (0.339) + (-1.666) = -1.327; $\theta_{S2} = 62.1°$; $\theta_{P3} = 127.0°$; $\theta_{S3} = 1.9°$; **or**
Solution 4: $Im(y_S)$ = (0.339) + (1.666) = 2.005; $\theta_{S2} = 62.1°$; $\theta_{P4} = 63.5°$; $\theta_{S4} = 52.1°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 4

1. z = 1.230 + j·1.105; Y = 1 / 50Ω / (1.230 + j·1.105) = 0.0090S + j·(-0.0081)S ; Γ = (z-1)/(z+1) = (1.230 + j·1.105-1)/(1.230 + j·1.105+1) = 0.280+j·(0.357) = 0.454∠51.9°, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20}$ = 0.107, Z_{0E} = 55.678Ω, Z_{0O} = 44.901Ω
b) Pc = 51.5μW = -12.882dBm ; Pin = Pc + C = -12.882dBm + 19.4dB = 6.518dBm = 4.485 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 4.485mW – 0.0515mW – 0 = 4.434 **mW** = 6.468 **dBm**



3. The series RC load with R = 33Ω and C = 0.362pF has Z_L = 33.00Ω + j·(-59.41)Ω at 7.4GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot \tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) tan(βl)=tan(2·π·2/6)=-1.732 ; cot(βl)= -0.577 ; Z_{in} = 116.64Ω∠52.0° = 71.79Ω + j·(91.92)Ω ;

b) If the line becomes short-circuited Z_L = 0 ; Z_{in} = j·(-95.26)Ω

4. a) G = $G_1 + G_2 + G_3$ = 17dB + 14dB + 18dB = 49dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.75dB=1.884, G_1 = 17dB=50.119, F_2 = 2.04dB=1.600, G_2 = 14dB=25.119, F_3 = 2.63dB=1.832,
F = 1.884 + (1.600−1)/50.119 + (1.832−1)/50.119/25.119 = 1.896 = 2.779dB

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

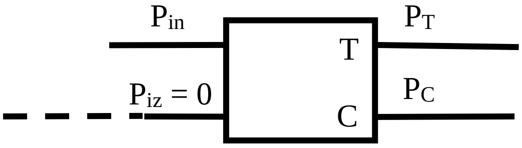
	Δ	|Δ|	K	μ
T1	-0.475+ j·(-0.082)	0.482	0.670	0.547
T2	-0.225+ j·(-0.237)	0.326	0.803	0.844

b) μ (T1) < μ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2)$ = 0.166 (L9/2023, S101)
d) For T2: MSG = $|S_{21}| / |S_{12}|$ = 26.558 = 14.242 dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}|$ = 0.223, $\arg(S_{22}^*)$ = 121.5° ; θ_{S1} = 170.7° ; $\mathrm{Im}(y_S)$ = -0.458 ; **or** θ_{S2} = 67.8° ; $\mathrm{Im}(y_S)$ = 0.458
S_{11}^* for T2: 2 solutions for the match, $|S_{11}|$ = 0.676, $\arg(S_{11}^*)$ = 114.0° ; θ_{S3} = 9.3° ; $\mathrm{Im}(y_S)$ = -1.835 ; **or** θ_{S4} = 56.7° ; $\mathrm{Im}(y_S)$ = 1.835
Combining the two schematics(L13/2023, S96), all lines with Z_0 = 50Ω:
Solution 1: $\mathrm{Im}(y_S)$ = (-0.458) + (-1.835) = -2.292; θ_{S1} = 170.7° ; θ_{P1} = 113.6° ; θ_{S3} = 9.3° ; **or**
Solution 2: $\mathrm{Im}(y_S)$ = (-0.458) + (1.835) = 1.377; θ_{S1} = 170.7° ; θ_{P2} = 54.0° ; θ_{S4} = 56.7° ; **or**
Solution 3: $\mathrm{Im}(y_S)$ = (0.458) + (-1.835) = -1.377; θ_{S2} = 67.8° ; θ_{P3} = 126.0° ; θ_{S3} = 9.3° ; **or**
Solution 4: $\mathrm{Im}(y_S)$ = (0.458) + (1.835) = 2.292; θ_{S2} = 67.8° ; θ_{P4} = 66.4° ; θ_{S4} = 56.7° ;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 5

1. $z = 1.005 - j\cdot 1.080$; $Y = 1 / 50\Omega / (1.005 - j\cdot 1.080) = 0.0092S + j\cdot(0.0099)S$; $\Gamma = (z-1)/(z+1) = (1.005 - j\cdot 1.080-1)/(1.005 - j\cdot 1.080+1) = 0.227+j\cdot(-0.416) = 0.474\angle -61.4°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.095$, $Z_{0E} = 55.026\Omega$, $Z_{0O} = 45.433\Omega$
b) $P_c = 126.0\mu W = -8.996dBm$; $P_{in} = P_c + C = -8.996dBm + 20.4dB = 11.404dBm = 13.816$ **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = $P_{in} - P_c - P_{iz} = 13.816mW - 0.1260mW - 0 = 13.690$ **mW** = 11.364 **dBm**



3. The shunt RL load with $R = 52\Omega$ and $L = 0.612nH$ has $Z_L = 13.98\Omega + j\cdot(23.05)\Omega$ at 8.2GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot \tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 5/8)=1.000$; $\cot(\beta l)= 1.000$; $Z_{in} = 134.47\Omega\angle 64.9° = 57.10\Omega + j\cdot(121.75)\Omega$;

b) If the line becomes short-circuited $Z_L = 0$; $Z_{in} = j\cdot(70.00)\Omega$

4. a) $G = G_1 + G_2 + G_3 = 11dB + 15dB + 17dB = 43dB$
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
$F_1 = 2.08dB=1.614$, $G_1 = 11dB=12.589$, $F_2 = 2.46dB=1.762$, $G_2 = 15dB=31.623$, $F_3 = 2.84dB=1.923$,
$F = 1.614 + (1.762-1)/12.589 + (1.923-1)/12.589/31.623 = 1.677 = 2.246dB$

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

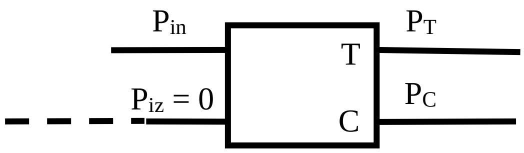
	Δ	$\lvert\Delta\rvert$	K	μ
T1	$-0.446+ j\cdot(0.165)$	0.475	0.788	0.681
T2	$-0.228+ j\cdot(-0.117)$	0.256	0.920	0.938

b) μ (T1) < μ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2) /(1-|S_{22}|^2) = 0.068$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 23.500 = 13.711$ dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.127$, $\arg(S_{22}^*) = 153.7°$; $\theta_{S1} = 151.8°$; $Im(y_S) = -0.256$; **or** $\theta_{S2} = 54.5°$; $Im(y_S) = 0.256$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.625$, $\arg(S_{11}^*) = 135.5°$; $\theta_{S3} = 176.6°$; $Im(y_S) = -1.601$; **or** $\theta_{S4} = 47.9°$; $Im(y_S) = 1.601$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.256) + (-1.601) = -1.857$; $\theta_{S1} = 151.8°$; $\theta_{P1} = 118.3°$; $\theta_{S3} = 176.6°$; **or**
Solution 2: $Im(y_S) = (-0.256) + (1.601) = 1.345$; $\theta_{S1} = 151.8°$; $\theta_{P2} = 53.4°$; $\theta_{S4} = 47.9°$; **or**
Solution 3: $Im(y_S) = (0.256) + (-1.601) = -1.345$; $\theta_{S2} = 54.5°$; $\theta_{P3} = 126.6°$; $\theta_{S3} = 176.6°$; **or**
Solution 4: $Im(y_S) = (0.256) + (1.601) = 1.857$; $\theta_{S2} = 54.5°$; $\theta_{P4} = 61.7°$; $\theta_{S4} = 47.9°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 6

1. $z = 0.865 + j\cdot0.795$; $Y = 1 / 50\Omega / (0.865 + j\cdot0.795) = 0.0125S + j\cdot(-0.0115)S$; $\Gamma = (z-1)/(z+1) = (0.865 + j\cdot0.795-1)/(0.865 + j\cdot0.795+1) = 0.093+j\cdot(0.387) = 0.398\angle76.6°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.097$, $Z_{0E} = 55.088\Omega$, $Z_{0O} = 45.382\Omega$
b) $P_c = 78.0\mu W = -11.079dBm$; $P_{in} = P_c + C = -11.079dBm + 20.3dB = 9.221dBm = 8.358$ **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = $P_{in} - P_c - P_{iz} = 8.358mW - 0.0780mW - 0 = 8.280$ **mW** = 9.180 **dBm**



3. The shunt RL load with $R = 35\Omega$ and $L = 0.733nH$ has $Z_L = 21.86\Omega + j\cdot(16.95)\Omega$ at 9.8GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot\cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot2/3)=1.732$; $\cot(\beta l)= 0.577$; $Z_{in} = 219.32\Omega\angle50.8° = 138.56\Omega + j\cdot(170.00)\Omega$;

b) If the line becomes short-circuited $Z_L = 0$; $Z_{in} = j\cdot(155.88)\Omega$

4. a) $G = G_1 + G_2 + G_3 = 12dB + 17dB + 18dB = 47dB$
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
$F_1 = 2.99dB=1.991$, $G_1 = 12dB=15.849$, $F_2 = 2.18dB=1.652$, $G_2 = 17dB=50.119$, $F_3 = 2.17dB=1.648$,
$F = 1.991 + (1.652-1)/15.849 + (1.648-1)/15.849/50.119 = 2.033 = 3.081dB$

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

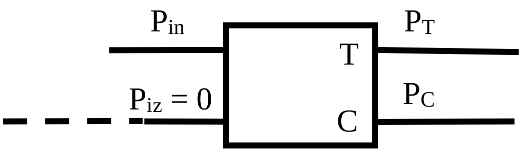
	Δ	|Δ|	K	μ'
T1	-0.366+ j·(0.297)	0.471	0.846	0.872
T2	-0.204+ j·(-0.056)	0.211	1.005	1.002

b) μ' (T1) < μ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2) /(1-|S_{22}|^2) = 0.039$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 22.564 = 13.534$ dB (L9/2023, S75) ; However $K = 1.005 > 1$ so maximum gain is $MAG = |S_{21}| / |S_{12}| \cdot [K - \sqrt{(K^2 - 1)}] = 20.410 = 13.098$ dB (L9/2023, S76)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.086$, $\arg(S_{22}^*) = -169.5°$; $\theta_{S1} = 132.2°$; $Im(y_S) = -0.173$; **or** $\theta_{S2} = 37.3°$; $Im(y_S) = 0.173$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.604$, $\arg(S_{11}^*) = 149.0°$; $\theta_{S3} = 169.1°$; $Im(y_S) = -1.516$; **or** $\theta_{S4} = 41.9°$; $Im(y_S) = 1.516$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.173) + (-1.516) = -1.688$; $\theta_{S1} = 132.2°$; $\theta_{P1} = 120.6°$; $\theta_{S3} = 169.1°$; **or**
Solution 2: $Im(y_S) = (-0.173) + (1.516) = 1.343$; $\theta_{S1} = 132.2°$; $\theta_{P2} = 53.3°$; $\theta_{S4} = 41.9°$; **or**
Solution 3: $Im(y_S) = (0.173) + (-1.516) = -1.343$; $\theta_{S2} = 37.3°$; $\theta_{P3} = 126.7°$; $\theta_{S3} = 169.1°$; **or**
Solution 4: $Im(y_S) = (0.173) + (1.516) = 1.688$; $\theta_{S2} = 37.3°$; $\theta_{P4} = 59.4°$; $\theta_{S4} = 41.9°$;
f) Schematic drawing, “T” shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 7

1. $z = 0.790 - j\cdot 1.270$; $Y = 1 / 50\Omega / (0.790 - j\cdot 1.270) = 0.0071S + j\cdot(0.0114)S$; $\Gamma = (z-1)/(z+1) = (0.790 - j\cdot 1.270-1)/(0.790 - j\cdot 1.270+1) = 0.257+j\cdot(-0.527) = 0.587\angle -64.0°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.126$, $Z_{0E} = 56.746\Omega$, $Z_{0O} = 44.056\Omega$
b) Pc = 111.0μW = -9.547dBm ; Pin = Pc + C = -9.547dBm + 18.0dB = 8.453dBm = 7.004 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 7.004mW – 0.1110mW – 0 = 6.893 **mW** = 8.384 **dBm**



3. The series RL load with R = 67Ω and L = 1.088nH has $Z_L = 67.00\Omega + j\cdot(53.32)\Omega$ at 7.8GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot \tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 1/3)=-1.732$; $\cot(\beta l)= -0.577$; $Z_{in} = 15.65\Omega\angle 27.8° = 13.84\Omega + j\cdot(7.31)\Omega$;

b) If the line becomes short-circuited $Z_L = 0$; $Z_{in} = j\cdot(-69.28)\Omega$

4. a) $G = G_1 + G_2 + G_3$ = 15dB + 14dB + 11dB = 40dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.23dB=1.671, G_1 = 15dB=31.623, F_2 = 2.01dB=1.589, G_2 = 14dB=25.119, F_3 = 2.74dB=1.879,
F = 1.671 + (1.589−1)/31.623 + (1.879−1)/31.623/25.119 = 1.691 = 2.281dB

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

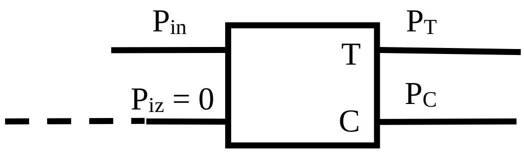
	Δ	|Δ|	K	μ
T1	-0.423+ j·(-0.243)	0.488	0.599	0.475
T2	-0.190+ j·(-0.322)	0.374	0.725	0.779

b) μ (T1) < μ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2) /(1-|S_{22}|^2)$ = 0.260 (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}|$ = 29.608 = 14.714 dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.281$, $\arg(S_{22}^*) = 105.1°$; $\theta_{S1} = 0.6°$; $Im(y_S) = -0.586$; **or** $\theta_{S2} = 74.3°$; $Im(y_S) = 0.586$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.721$, $\arg(S_{11}^*) = 100.0°$; $\theta_{S3} = 18.1°$; $Im(y_S) = -2.081$; **or** $\theta_{S4} = 61.9°$; $Im(y_S) = 2.081$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S)$ = (-0.586) + (-2.081) = -2.667; $\theta_{S1} = 0.6°$; $\theta_{P1} = 110.6°$; $\theta_{S3} = 18.1°$; **or**
Solution 2: $Im(y_S)$ = (-0.586) + (2.081) = 1.495; $\theta_{S1} = 0.6°$; $\theta_{P2} = 56.2°$; $\theta_{S4} = 61.9°$; **or**
Solution 3: $Im(y_S)$ = (0.586) + (-2.081) = -1.495; $\theta_{S2} = 74.3°$; $\theta_{P3} = 123.8°$; $\theta_{S3} = 18.1°$; **or**
Solution 4: $Im(y_S)$ = (0.586) + (2.081) = 2.667; $\theta_{S2} = 74.3°$; $\theta_{P4} = 69.4°$; $\theta_{S4} = 61.9°$;
f) Schematic drawing, “T” shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 8

1. $z = 1.060 - j\cdot 0.990$; $Y = 1 / 50\Omega / (1.060 - j\cdot 0.990) = 0.0101S + j\cdot(0.0094)S$; $\Gamma = (z-1)/(z+1) = (1.060 - j\cdot 0.990-1)/(1.060 - j\cdot 0.990+1) = 0.211+j\cdot(-0.379) = 0.434\angle -60.9°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.114$, $Z_{0E} = 56.037\Omega$, $Z_{0O} = 44.613\Omega$
b) $P_c = 100.5\mu W = -9.978dBm$; $P_{in} = P_c + C = -9.978dBm + 18.9dB = 8.922dBm = 7.801$ **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = $P_{in} - P_c - P_{iz} = 7.801mW - 0.1005mW - 0 = 7.701$ **mW** = 8.865 **dBm**



3. The series RC load with $R = 58\Omega$ and $C = 0.518pF$ has $Z_L = 58.00\Omega + j\cdot(-46.55)\Omega$ at 6.6GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0\cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot \tan(\beta l)}{1 + j\cdot Z_L/Z_0\cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 1/3)=-1.732$; $\cot(\beta l)= -0.577$; $Z_{in} = 138.45\Omega\angle 21.4° = 128.91\Omega + j\cdot(50.53)\Omega$;

b) If the line becomes short-circuited $Z_L = 0$; $Z_{in} = j\cdot(-129.90)\Omega$

4. a) $G = G_1 + G_2 + G_3 = 12dB + 17dB + 12dB = 41dB$
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
$F_1 = 2.48dB=1.770$, $G_1 = 12dB=15.849$, $F_2 = 2.27dB=1.687$, $G_2 = 17dB=50.119$, $F_3 = 2.55dB=1.799$,
$F = 1.770 + (1.687-1)/15.849 + (1.799-1)/15.849/50.119 = 1.814 = 2.587dB$

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

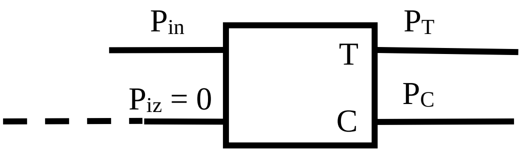
	Δ	$\|\Delta\|$	K	μ
T1	$-0.036+ j\cdot(0.489)$	0.490	0.941	0.898
T2	$-0.118+ j\cdot(0.007)$	0.118	1.203	1.150

b) μ (T1) < μ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2) /(1-|S_{22}|^2) = 0.067$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 20.382 = 13.092$ dB (L9/2023, S75) ; However $K = 1.203 > 1$ so maximum gain is $MAG = |S_{21}| / |S_{12}| \cdot [K - \sqrt{(K^2 - 1)}] = 10.896 = 10.373$ dB (L9/2023, S76)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.169$, $\arg(S_{22}^*) = -59.3°$; $\theta_{S1} = 79.5°$; $Im(y_S) = -0.343$; **or** $\theta_{S2} = 159.8°$; $Im(y_S) = 0.343$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.572$, $\arg(S_{11}^*) = -179.0°$; $\theta_{S3} = 151.9°$; $Im(y_S) = -1.395$; **or** $\theta_{S4} = 27.1°$; $Im(y_S) = 1.395$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.343) + (-1.395) = -1.738$; $\theta_{S1} = 79.5°$; $\theta_{P1} = 119.9°$; $\theta_{S3} = 151.9°$; **or**
Solution 2: $Im(y_S) = (-0.343) + (1.395) = 1.052$; $\theta_{S1} = 79.5°$; $\theta_{P2} = 46.4°$; $\theta_{S4} = 27.1°$; **or**
Solution 3: $Im(y_S) = (0.343) + (-1.395) = -1.052$; $\theta_{S2} = 159.8°$; $\theta_{P3} = 133.6°$; $\theta_{S3} = 151.9°$; **or**
Solution 4: $Im(y_S) = (0.343) + (1.395) = 1.738$; $\theta_{S2} = 159.8°$; $\theta_{P4} = 60.1°$; $\theta_{S4} = 27.1°$;
f) Schematic drawing, “T” shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 9

1. $z = 1.125 + j\cdot 0.935$; $Y = 1 / 50\Omega / (1.125 + j\cdot 0.935) = 0.0105S + j\cdot(-0.0087)S$; $\Gamma = (z-1)/(z+1) = (1.125 + j\cdot 0.935-1)/(1.125 + j\cdot 0.935+1) = 0.211+j\cdot(0.347) = 0.406\angle 58.6°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.135$, $Z_{0E} = 57.268\Omega$, $Z_{0O} = 43.654\Omega$
b) $P_c = 148.0\mu W = -8.297dBm$; $P_{in} = P_c + C = -8.297dBm + 17.4dB = 9.103dBm = 8.133$ **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = $P_{in} – P_c – P_{iz} = 8.133mW – 0.1480mW – 0 = 7.985$ **mW** = 9.023 **dBm**



3. The series RL load with $R = 42\Omega$ and $L = 1.187nH$ has $Z_L = 42.00\Omega + j\cdot(71.60)\Omega$ at 9.6GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0\cdot\tan(\beta l)}{Z_0 + j\cdot Z_L\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot\cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 2/3)=1.732$; $\cot(\beta l)= 0.577$; $Z_{in} = 94.38\Omega\angle -57.6° = 50.54\Omega + j\cdot(-79.70)\Omega$;

b) If the line becomes short-circuited $Z_L = 0$; $Z_{in} = j\cdot(95.26)\Omega$

4. a) $G = G_1 + G_2 + G_3 = 12dB + 12dB + 18dB = 42dB$
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
$F_1 = 2.84dB=1.923$, $G_1 = 12dB=15.849$, $F_2 = 2.65dB=1.841$, $G_2 = 12dB=15.849$, $F_3 = 2.45dB=1.758$,
$F = 1.923 + (1.841-1)/15.849 + (1.758-1)/15.849/15.849 = 1.979 = 2.965dB$

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

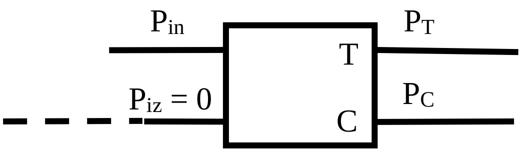
	Δ	|Δ|	K	μ'
T1	-0.269+ j·(0.399)	0.481	0.881	0.896
T2	-0.174+ j·(-0.022)	0.175	1.086	1.039

b) μ' (T1) < μ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2) /(1-|S_{22}|^2) = 0.037$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 21.800 = 13.385$ dB (L9/2023, S75) ; However $K = 1.086 > 1$ so maximum gain is $MAG = |S_{21}| / |S_{12}| \cdot [K - \sqrt{(K^2 - 1)}] = 14.435 = 11.594$ dB (L9/2023, S76)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.088$, $\arg(S_{22}^*) = -112.1°$; $\theta_{S1} = 103.6°$; $\mathrm{Im}(y_S) = -0.177$; **or** $\theta_{S2} = 8.5°$; $\mathrm{Im}(y_S) = 0.177$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.586$, $\arg(S_{11}^*) = 161.0°$; $\theta_{S3} = 162.4°$; $\mathrm{Im}(y_S) = -1.446$; **or** $\theta_{S4} = 36.6°$; $\mathrm{Im}(y_S) = 1.446$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $\mathrm{Im}(y_S) = (-0.177) + (-1.446) = -1.623$; $\theta_{S1} = 103.6°$; $\theta_{P1} = 121.6°$; $\theta_{S3} = 162.4°$; **or**
Solution 2: $\mathrm{Im}(y_S) = (-0.177) + (1.446) = 1.270$; $\theta_{S1} = 103.6°$; $\theta_{P2} = 51.8°$; $\theta_{S4} = 36.6°$; **or**
Solution 3: $\mathrm{Im}(y_S) = (0.177) + (-1.446) = -1.270$; $\theta_{S2} = 8.5°$; $\theta_{P3} = 128.2°$; $\theta_{S3} = 162.4°$; **or**
Solution 4: $\mathrm{Im}(y_S) = (0.177) + (1.446) = 1.623$; $\theta_{S2} = 8.5°$; $\theta_{P4} = 58.4°$; $\theta_{S4} = 36.6°$;
f) Schematic drawing, “T” shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 10

1. z = 1.180 − j·0.805; Y = 1 / 50Ω / (1.180 − j·0.805) = 0.0116S + j·(0.0079)S ; Γ = (z-1)/(z+1) = (1.180 − j·0.805-1)/(1.180 − j·0.805+1) = 0.193+j·(-0.298) = 0.355∠-57.1°, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20}$ = 0.074, Z_{0E} = 53.855Ω, Z_{0O} = 46.421Ω
b) Pc = 52.0μW = -12.840dBm ; Pin = Pc + C = -12.840dBm + 22.6dB = 9.760dBm = 9.462 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 9.462mW – 0.0520mW – 0 = 9.410 **mW** = 9.736 **dBm**



3. The series RL load with R = 57Ω and L = 1.180nH has Z_L = 57.00Ω + j·(55.61)Ω at 7.5GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j \cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j \cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j \cdot \tan(\beta l)}{1 + j \cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j \cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) tan(βl)=tan(2·π·2/6)=-1.732 ; cot(βl)= -0.577 ; Z_{in} = 24.25Ω∠-8.0° = 24.01Ω + j·(-3.38)Ω ;

b) If the line becomes short-circuited Z_L = 0 ; Z_{in} = j·(-103.92)Ω

4. a) G = $G_1 + G_2 + G_3$ = 10dB + 15dB + 17dB = 42dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.96dB=1.977, G_1 = 10dB=10.000, F_2 = 2.65dB=1.841, G_2 = 15dB=31.623, F_3 = 2.11dB=1.626,
F = 1.977 + (1.841−1)/10.000 + (1.626−1)/10.000/31.623 = 2.063 = 3.145dB

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

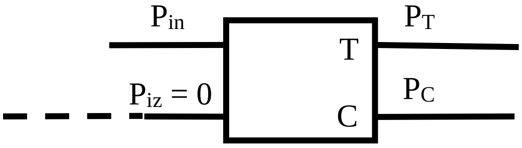
	Δ	|Δ|	K	μ
T1	-0.397+ j·(-0.284)	0.488	0.584	0.463
T2	-0.174+ j·(-0.348)	0.389	0.699	0.757

b) μ (T1) < μ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2)$ = 0.286 (L9/2023, S101)
d) For T2: MSG = $|S_{21}| / |S_{12}|$ = 30.526 = 14.847 dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}|$ = 0.295, $\arg(S_{22}^*)$ = 100.7° ; θ_{S1} = 3.2° ; $Im(y_S)$ = -0.617 ; **or** θ_{S2} = 76.1° ; $Im(y_S)$ = 0.617
S_{11}^* for T2: 2 solutions for the match, $|S_{11}|$ = 0.735, $\arg(S_{11}^*)$ = 96.0° ; θ_{S3} = 20.7° ; $Im(y_S)$ = -2.168 ; **or** θ_{S4} = 63.3° ; $Im(y_S)$ = 2.168
Combining the two schematics(L13/2023, S96), all lines with Z_0 = 50Ω:
Solution 1: $Im(y_S)$ = (-0.617) + (-2.168) = -2.785; θ_{S1} = 3.2° ; θ_{P1} = 109.7° ; θ_{S3} = 20.7° ; **or**
Solution 2: $Im(y_S)$ = (-0.617) + (2.168) = 1.550; θ_{S1} = 3.2° ; θ_{P2} = 57.2° ; θ_{S4} = 63.3° ; **or**
Solution 3: $Im(y_S)$ = (0.617) + (-2.168) = -1.550; θ_{S2} = 76.1° ; θ_{P3} = 122.8° ; θ_{S3} = 20.7° ; **or**
Solution 4: $Im(y_S)$ = (0.617) + (2.168) = 2.785; θ_{S2} = 76.1° ; θ_{P4} = 70.3° ; θ_{S4} = 63.3° ;
f) Schematic drawing, “T” shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 11

1. $z = 1.235 - j\cdot 1.250$; $Y = 1 / 50\Omega / (1.235 - j\cdot 1.250) = 0.0080S + j\cdot(0.0081)S$; $\Gamma = (z-1)/(z+1) = (1.235 - j\cdot 1.250-1)/(1.235 - j\cdot 1.250+1) = 0.318+j\cdot(-0.381) = 0.497\angle -50.1°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.110$, $Z_{0E} = 55.819\Omega$, $Z_{0O} = 44.788\Omega$
b) $P_c = 68.5\mu W = -11.643dBm$; $P_{in} = P_c + C = -11.643dBm + 19.2dB = 7.557dBm = 5.698$ **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 5.698mW – 0.0685mW – 0 = 5.629 **mW** = 7.504 **dBm**



3. The shunt RL load with R = 32Ω and L = 1.335nH has $Z_L = 23.99\Omega + j\cdot(13.86)\Omega$ at 6.6GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot \tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 2/5)=-0.727$; $\cot(\beta l)= -1.376$; $Z_{in} = 34.65\Omega\angle -41.2° = 26.07\Omega + j\cdot(-22.83)\Omega$;

b) If the line becomes open-circuited $Z_L = \infty$; $Z_{in} = j\cdot(89.46)\Omega$

4. a) $G = G_1 + G_2 + G_3 = 14dB + 14dB + 17dB = 45dB$
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
$F_1 = 2.37dB=1.726$, $G_1 = 14dB=25.119$, $F_2 = 2.86dB=1.932$, $G_2 = 14dB=25.119$, $F_3 = 2.30dB=1.698$,
$F = 1.726 + (1.932-1)/25.119 + (1.698-1)/25.119/25.119 = 1.764 = 2.465dB$

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

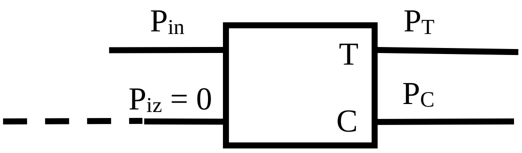
	Δ	|Δ|	K	μ
T1	-0.335+ j·(0.330)	0.471	0.852	0.768
T2	-0.194+ j·(-0.043)	0.199	1.031	1.023

b) μ (T1) < μ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2) = 0.039$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 22.309 = 13.485$ dB (L9/2023, S75) ; However K = 1.031 > 1 so maximum gain is $MAG = |S_{21}| / |S_{12}| \cdot [K - \sqrt{(K^2 - 1)}] = 17.415 = 12.409$ dB (L9/2023, S76)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.087$, $\arg(S_{22}^*) = -150.4°$; $\theta_{S1} = 122.7°$; $Im(y_S) = -0.175$; **or** $\theta_{S2} = 27.7°$; $Im(y_S) = 0.175$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.598$, $\arg(S_{11}^*) = 153.0°$; $\theta_{S3} = 166.9°$; $Im(y_S) = -1.492$; **or** $\theta_{S4} = 40.1°$; $Im(y_S) = 1.492$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.175) + (-1.492) = -1.667$; $\theta_{S1} = 122.7°$; $\theta_{P1} = 121.0°$; $\theta_{S3} = 166.9°$; **or**
Solution 2: $Im(y_S) = (-0.175) + (1.492) = 1.318$; $\theta_{S1} = 122.7°$; $\theta_{P2} = 52.8°$; $\theta_{S4} = 40.1°$; **or**
Solution 3: $Im(y_S) = (0.175) + (-1.492) = -1.318$; $\theta_{S2} = 27.7°$; $\theta_{P3} = 127.2°$; $\theta_{S3} = 166.9°$; **or**
Solution 4: $Im(y_S) = (0.175) + (1.492) = 1.667$; $\theta_{S2} = 27.7°$; $\theta_{P4} = 59.0°$; $\theta_{S4} = 40.1°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 12

1. $z = 1.020 - j\cdot 0.720$; $Y = 1 / 50\Omega / (1.020 - j\cdot 0.720) = 0.0131S + j\cdot(0.0092)S$; $\Gamma = (z-1)/(z+1) = (1.020 - j\cdot 0.720-1)/(1.020 - j\cdot 0.720+1) = 0.122+j\cdot(-0.313) = 0.336\angle -68.8°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.130$, $Z_{0E} = 57.002\Omega$, $Z_{0O} = 43.858\Omega$
b) $P_c = 146.0\mu W = -8.356dBm$; $P_{in} = P_c + C = -8.356dBm + 17.7dB = 9.344dBm = 8.597$ **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = $P_{in} - P_c - P_{iz} = 8.597mW - 0.1460mW - 0 = 8.451$ **mW** = 9.269 **dBm**



3. The shunt RC load with R = 69Ω and C = 0.297pF has $Z_L = 30.60\Omega + j\cdot(-34.28)\Omega$ at 8.7GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0\cdot\tan(\beta l)}{Z_0 + j\cdot Z_L\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot\cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 4/5)=-3.078$; $\cot(\beta l)= -0.325$; $Z_{in} = 328.92\Omega\angle 11.7° = 322.07\Omega + j\cdot(66.77)\Omega$;

b) If the line becomes short-circuited $Z_L = 0$; $Z_{in} = j\cdot(-292.38)\Omega$

4. a) $G = G_1 + G_2 + G_3 = 13dB + 11dB + 10dB = 34dB$
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
$F_1 = 2.66dB=1.845$, $G_1 = 13dB=19.953$, $F_2 = 2.54dB=1.795$, $G_2 = 11dB=12.589$, $F_3 = 2.41dB=1.742$,
$F = 1.845 + (1.795-1)/19.953 + (1.742-1)/19.953/12.589 = 1.888 = 2.760dB$

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

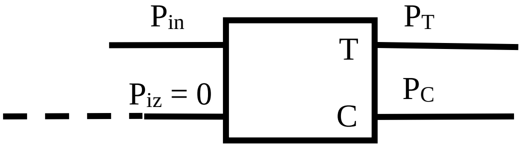
	Δ	|Δ|	K	μ'
T1	-0.303+ j·(0.362)	0.472	0.865	0.886
T2	-0.184+ j·(-0.031)	0.187	1.058	1.026

b) μ' (T1) < μ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2) /(1-|S_{22}|^2) = 0.038$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 22.055 = 13.435$ dB (L9/2023, S75) ; However K = 1.058 > 1 so maximum gain is $MAG = |S_{21}| / |S_{12}| \cdot [K - \sqrt{(K^2 - 1)}] = 15.719 = 11.964$ dB (L9/2023, S76)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.087$, $\arg(S_{22}^*) = -131.2°$; $\theta_{S1} = 113.1°$; $\mathrm{Im}(y_S) = -0.175$; **or** $\theta_{S2} = 18.1°$; $\mathrm{Im}(y_S) = 0.175$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.592$, $\arg(S_{11}^*) = 157.0°$; $\theta_{S3} = 164.6°$; $\mathrm{Im}(y_S) = -1.469$; **or** $\theta_{S4} = 38.4°$; $\mathrm{Im}(y_S) = 1.469$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $\mathrm{Im}(y_S) = (-0.175) + (-1.469) = -1.644$; $\theta_{S1} = 113.1°$; $\theta_{P1} = 121.3°$; $\theta_{S3} = 164.6°$; **or**
Solution 2: $\mathrm{Im}(y_S) = (-0.175) + (1.469) = 1.294$; $\theta_{S1} = 113.1°$; $\theta_{P2} = 52.3°$; $\theta_{S4} = 38.4°$; **or**
Solution 3: $\mathrm{Im}(y_S) = (0.175) + (-1.469) = -1.294$; $\theta_{S2} = 18.1°$; $\theta_{P3} = 127.7°$; $\theta_{S3} = 164.6°$; **or**
Solution 4: $\mathrm{Im}(y_S) = (0.175) + (1.469) = 1.644$; $\theta_{S2} = 18.1°$; $\theta_{P4} = 58.7°$; $\theta_{S4} = 38.4°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 13

1. $z = 0.830 + j\cdot 1.195$; $Y = 1 / 50\Omega / (0.830 + j\cdot 1.195) = 0.0078S + j\cdot(-0.0113)S$; $\Gamma = (z-1)/(z+1) = (0.830 + j\cdot 1.195-1)/(0.830 + j\cdot 1.195+1) = 0.234+j\cdot(0.500) = 0.552\angle 65.0°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.115$, $Z_{0E} = 56.112\Omega$, $Z_{0O} = 44.554\Omega$
b) $Pc = 86.5\mu W = -10.630dBm$; $Pin = Pc + C = -10.630dBm + 18.8dB = 8.170dBm = 6.562$ **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 6.562mW – 0.0865mW – 0 = 6.475 **mW** = 8.113 **dBm**



3. The shunt RL load with R = 59Ω and L = 0.986nH has $Z_L = 19.14\Omega + j\cdot(27.62)\Omega$ at 6.6GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot \tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 2/3)=1.732$; $\cot(\beta l)= 0.577$; $Z_{in} = 145.08\Omega\angle -15.2° = 140.02\Omega + j\cdot(-37.99)\Omega$;

b) If the line becomes open-circuited $Z_L = \infty$; $Z_{in} = j\cdot(-25.98)\Omega$

4. a) $G = G_1 + G_2 + G_3 = 15dB + 15dB + 14dB = 44dB$
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
$F_1 = 2.04dB=1.600$, $G_1 = 15dB=31.623$, $F_2 = 2.60dB=1.820$, $G_2 = 15dB=31.623$, $F_3 = 2.08dB=1.614$,
$F = 1.600 + (1.820-1)/31.623 + (1.614-1)/31.623/31.623 = 1.626 = 2.111dB$

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

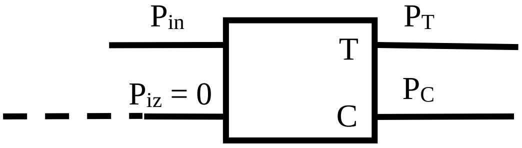
	Δ	|Δ|	K	μ
T1	-0.336+ j·(-0.365)	0.496	0.553	0.431
T2	-0.132+ j·(-0.399)	0.421	0.650	0.712

b) μ (T1) < μ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2) /(1-|S_{22}|^2) = 0.350$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 32.484 = 15.117$ dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.322$, $\arg(S_{22}^*) = 91.8°$; $\theta_{S1} = 8.5°$; $Im(y_S) = -0.680$; **or** $\theta_{S2} = 79.7°$; $Im(y_S) = 0.680$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.763$, $\arg(S_{11}^*) = 88.0°$; $\theta_{S3} = 25.9°$; $Im(y_S) = -2.361$; **or** $\theta_{S4} = 66.1°$; $Im(y_S) = 2.361$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.680) + (-2.361) = -3.041$; $\theta_{S1} = 8.5°$; $\theta_{P1} = 108.2°$; $\theta_{S3} = 25.9°$; **or**
Solution 2: $Im(y_S) = (-0.680) + (2.361) = 1.681$; $\theta_{S1} = 8.5°$; $\theta_{P2} = 59.2°$; $\theta_{S4} = 66.1°$; **or**
Solution 3: $Im(y_S) = (0.680) + (-2.361) = -1.681$; $\theta_{S2} = 79.7°$; $\theta_{P3} = 120.8°$; $\theta_{S3} = 25.9°$; **or**
Solution 4: $Im(y_S) = (0.680) + (2.361) = 3.041$; $\theta_{S2} = 79.7°$; $\theta_{P4} = 71.8°$; $\theta_{S4} = 66.1°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 14

1. $z = 1.030 - j\cdot 1.085$; $Y = 1 / 50\Omega / (1.030 - j\cdot 1.085) = 0.0092S + j\cdot(0.0097)S$; $\Gamma = (z-1)/(z+1) = (1.030 - j\cdot 1.085-1)/(1.030 - j\cdot 1.085+1) = 0.234+j\cdot(-0.410) = 0.472\angle -60.3°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.080$, $Z_{0E} = 54.193\Omega$, $Z_{0O} = 46.132\Omega$
b) $P_c = 141.5\mu W = -8.492dBm$; $P_{in} = P_c + C = -8.492dBm + 21.9dB = 13.408dBm = 21.916$ **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = $P_{in} - P_c - P_{iz} = 21.916mW - 0.1415mW - 0 = 21.774$ **mW** = 13.379 **dBm**



3. The shunt RC load with $R = 64\Omega$ and $C = 0.615pF$ has $Z_L = 11.59\Omega + j\cdot(-24.64)\Omega$ at 8.6GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot \tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 2/3)=1.732$; $\cot(\beta l)= 0.577$; $Z_{in} = 16.49\Omega\angle 57.7° = 8.82\Omega + j\cdot(13.93)\Omega$;

b) If the line becomes short-circuited $Z_L = 0$; $Z_{in} = j\cdot(60.62)\Omega$

4. a) $G = G_1 + G_2 + G_3 = 17dB + 17dB + 16dB = 50dB$
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
$F_1 = 2.38dB=1.730$, $G_1 = 17dB=50.119$, $F_2 = 2.74dB=1.879$, $G_2 = 17dB=50.119$, $F_3 = 2.25dB=1.679$,
$F = 1.730 + (1.879-1)/50.119 + (1.679-1)/50.119/50.119 = 1.748 = 2.424dB$

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

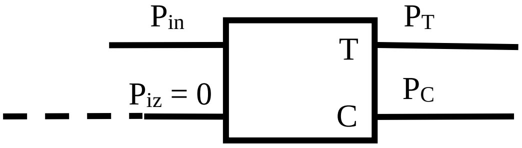
	Δ	|Δ|	K	μ
T1	-0.318+ j·(-0.380)	0.496	0.547	0.426
T2	-0.119+ j·(-0.412)	0.429	0.638	0.701

b) μ (T1) < μ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2) /(1-|S_{22}|^2) = 0.366$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 33.000 = 15.185$ dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.329$, $\arg(S_{22}^*) = 89.6°$; $\theta_{S1} = 9.8°$; $Im(y_S) = -0.697$; **or** $\theta_{S2} = 80.6°$; $Im(y_S) = 0.697$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.770$, $\arg(S_{11}^*) = 86.0°$; $\theta_{S3} = 27.2°$; $Im(y_S) = -2.414$; **or** $\theta_{S4} = 66.8°$; $Im(y_S) = 2.414$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.697) + (-2.414) = -3.110$; $\theta_{S1} = 9.8°$; $\theta_{P1} = 107.8°$; $\theta_{S3} = 27.2°$; **or**
Solution 2: $Im(y_S) = (-0.697) + (2.414) = 1.717$; $\theta_{S1} = 9.8°$; $\theta_{P2} = 59.8°$; $\theta_{S4} = 66.8°$; **or**
Solution 3: $Im(y_S) = (0.697) + (-2.414) = -1.717$; $\theta_{S2} = 80.6°$; $\theta_{P3} = 120.2°$; $\theta_{S3} = 27.2°$; **or**
Solution 4: $Im(y_S) = (0.697) + (2.414) = 3.110$; $\theta_{S2} = 80.6°$; $\theta_{P4} = 72.2°$; $\theta_{S4} = 66.8°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 15

1. $z = 1.245 + j\cdot 1.150$; $Y = 1 / 50\Omega / (1.245 + j\cdot 1.150) = 0.0087S + j\cdot(-0.0080)S$; $\Gamma = (z-1)/(z+1) = (1.245 + j\cdot 1.150-1)/(1.245 + j\cdot 1.150+1) = 0.294+j\cdot(0.361) = 0.466\angle 50.8°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.088$, $Z_{0E} = 54.618\Omega$, $Z_{0O} = 45.773\Omega$
b) Pc = 91.0μW = -10.410dBm ; Pin = Pc + C = -10.410dBm + 21.1dB = 10.690dBm = 11.723 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 11.723mW – 0.0910mW – 0 = 11.632 **mW** = 10.657 **dBm**



3. The shunt RC load with R = 40Ω and C = 0.638pF has $Z_L = 17.42\Omega + j\cdot(-19.83)\Omega$ at 7.1GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0\cdot\tan(\beta l)}{Z_0 + j\cdot Z_L\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot\cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 3/5)=0.727$; $\cot(\beta l)= 1.376$; $Z_{in} = 16.04\Omega\angle 24.4° = 14.61\Omega + j\cdot(6.63)\Omega$;

b) If the line becomes open-circuited $Z_L = \infty$; $Z_{in} = j\cdot(-61.94)\Omega$

4. a) $G = G_1 + G_2 + G_3$ = 16dB + 17dB + 18dB = 51dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.08dB=1.614, G_1 = 16dB=39.811, F_2 = 2.53dB=1.791, G_2 = 17dB=50.119, F_3 = 2.98dB=1.986,
F = 1.614 + (1.791−1)/39.811 + (1.986−1)/39.811/50.119 = 1.635 = 2.134dB

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

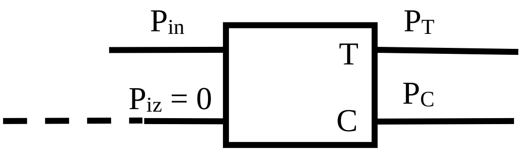
	Δ	|Δ|	K	μ
T1	-0.181+ j·(0.450)	0.484	0.908	0.845
T2	-0.152+ j·(-0.006)	0.152	1.135	1.101

b) μ (T1) < μ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2) = 0.044$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}|$ = 21.255 = 13.275 dB (L9/2023, S75) ; However K = 1.135 > 1 so maximum gain is $MAG = |S_{21}| / |S_{12}| \cdot [K - \sqrt{(K^2 - 1)}]$ = 12.703 = 11.039 dB (L9/2023, S76)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.108$, $\arg(S_{22}^*) = -84.5°$; $\theta_{S1} = 90.3°$; $Im(y_S) = -0.217$; **or** $\theta_{S2} = 174.1°$; $Im(y_S) = 0.217$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.578$, $\arg(S_{11}^*) = 169.0°$; $\theta_{S3} = 158.2°$; $Im(y_S) = -1.417$; **or** $\theta_{S4} = 32.8°$; $Im(y_S) = 1.417$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.217) + (-1.417) = -1.634$; $\theta_{S1} = 90.3°$; $\theta_{P1} = 121.5°$; $\theta_{S3} = 158.2°$; **or**
Solution 2: $Im(y_S) = (-0.217) + (1.417) = 1.199$; $\theta_{S1} = 90.3°$; $\theta_{P2} = 50.2°$; $\theta_{S4} = 32.8°$; **or**
Solution 3: $Im(y_S) = (0.217) + (-1.417) = -1.199$; $\theta_{S2} = 174.1°$; $\theta_{P3} = 129.8°$; $\theta_{S3} = 158.2°$; **or**
Solution 4: $Im(y_S) = (0.217) + (1.417) = 1.634$; $\theta_{S2} = 174.1°$; $\theta_{P4} = 58.5°$; $\theta_{S4} = 32.8°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 16

1. $z = 1.050 + j\cdot 0.890$; $Y = 1 / 50\Omega / (1.050 + j\cdot 0.890) = 0.0111S + j\cdot(-0.0094)S$; $\Gamma = (z-1)/(z+1) = (1.050 + j\cdot 0.890-1)/(1.050 + j\cdot 0.890+1) = 0.179+j\cdot(0.356) = 0.399\angle 63.3°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.094$, $Z_{0E} = 54.966\Omega$, $Z_{0O} = 45.483\Omega$
b) Pc = 112.5μW = -9.488dBm ; Pin = Pc + C = -9.488dBm + 20.5dB = 11.012dBm = 12.623 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 12.623mW – 0.1125mW – 0 = 12.510 **mW** = 10.973 **dBm**



3. The shunt RL load with R = 70Ω and L = 0.961nH has $Z_L = 21.04\Omega + j\cdot(32.10)\Omega$ at 7.6GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0\cdot\tan(\beta l)}{Z_0 + j\cdot Z_L\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot\cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 2/6)=-1.732$; $\cot(\beta l)= -0.577$; $Z_{in} = 16.71\Omega\angle -39.6° = 12.87\Omega + j\cdot(-10.65)\Omega$;

b) If the line becomes open-circuited $Z_L = \infty$; $Z_{in} = j\cdot(23.09)\Omega$

4. a) $G = G_1 + G_2 + G_3$ = 15dB + 17dB + 11dB = 43dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.06dB=1.607, G_1 = 15dB=31.623, F_2 = 2.04dB=1.600, G_2 = 17dB=50.119, F_3 = 2.36dB=1.722,
F = 1.607 + (1.600−1)/31.623 + (1.722−1)/31.623/50.119 = 1.626 = 2.112dB

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

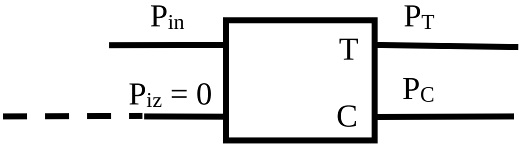
	Δ	|Δ|	K	μ
T1	-0.463+ j·(0.105)	0.475	0.763	0.652
T2	-0.233+ j·(-0.150)	0.277	0.887	0.912

b) μ (T1) < μ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2)$ = 0.086 (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}|$ = 23.909 = 13.786 dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.151$, $\arg(S_{22}^*) = 143.1°$; $\theta_{S1} = 157.8°$; $Im(y_S) = -0.306$; **or** $\theta_{S2} = 59.1°$; $Im(y_S) = 0.306$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.634$, $\arg(S_{11}^*) = 129.8°$; $\theta_{S3} = 179.8°$; $Im(y_S) = -1.640$; **or** $\theta_{S4} = 50.4°$; $Im(y_S) = 1.640$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.306) + (-1.640) = -1.945$; $\theta_{S1} = 157.8°$; $\theta_{P1} = 117.2°$; $\theta_{S3} = 179.8°$; **or**
Solution 2: $Im(y_S) = (-0.306) + (1.640) = 1.334$; $\theta_{S1} = 157.8°$; $\theta_{P2} = 53.1°$; $\theta_{S4} = 50.4°$; **or**
Solution 3: $Im(y_S) = (0.306) + (-1.640) = -1.334$; $\theta_{S2} = 59.1°$; $\theta_{P3} = 126.9°$; $\theta_{S3} = 179.8°$; **or**
Solution 4: $Im(y_S) = (0.306) + (1.640) = 1.945$; $\theta_{S2} = 59.1°$; $\theta_{P4} = 62.8°$; $\theta_{S4} = 50.4°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 17

1. $z = 0.750 + j\cdot 0.940$; $Y = 1 / 50\Omega / (0.750 + j\cdot 0.940) = 0.0104S + j\cdot(-0.0130)S$; $\Gamma = (z-1)/(z+1) = (0.750 + j\cdot 0.940-1)/(0.750 + j\cdot 0.940+1) = 0.113+j\cdot(0.476) = 0.490\angle 76.7°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.105$, $Z_{0E} = 55.541\Omega$, $Z_{0O} = 45.012\Omega$
b) $P_c = 126.5\mu W = -8.979dBm$; $P_{in} = P_c + C = -8.979dBm + 19.6dB = 10.621dBm = 11.537$ **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 11.537mW – 0.1265mW – 0 = 11.410 **mW** = 10.573 **dBm**



3. The series RC load with R = 70Ω and C = 0.609pF has $Z_L = 70.00\Omega + j\cdot(-38.43)\Omega$ at 6.8GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 2/8)=\infty$; $\cot(\beta l)= 0.000$; $Z_{in} = 15.34\Omega\angle 28.8° = 13.45\Omega + j\cdot(7.38)\Omega$;

b) If the line becomes short-circuited $Z_L = 0$; $Z_{in} = j\cdot(0.00)\Omega$

4. a) $G = G_1 + G_2 + G_3 = 16dB + 19dB + 19dB = 54dB$
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
$F_1 = 2.65dB=1.841$, $G_1 = 16dB=39.811$, $F_2 = 2.97dB=1.982$, $G_2 = 19dB=79.433$, $F_3 = 2.70dB=1.862$,
$F = 1.841 + (1.982-1)/39.811 + (1.862-1)/39.811/79.433 = 1.866 = 2.708dB$

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

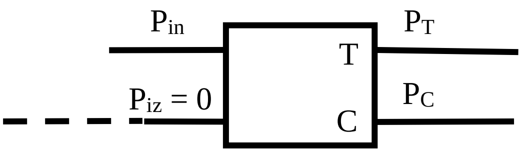
	Δ	|Δ|	K	μ
T1	-0.464+ j·(-0.155)	0.489	0.633	0.507
T2	-0.213+ j·(-0.272)	0.346	0.773	0.819

b) μ (T1) < μ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2) = 0.209$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 27.851 = 14.448$ dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.251$, $\arg(S_{22}^*) = 114.2°$; $\theta_{S1} = 175.2°$; $Im(y_S) = -0.519$; **or** $\theta_{S2} = 70.6°$; $Im(y_S) = 0.519$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.694$, $\arg(S_{11}^*) = 108.0°$; $\theta_{S3} = 13.0°$; $Im(y_S) = -1.928$; **or** $\theta_{S4} = 59.0°$; $Im(y_S) = 1.928$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.519) + (-1.928) = -2.446$; $\theta_{S1} = 175.2°$; $\theta_{P1} = 112.2°$; $\theta_{S3} = 13.0°$; **or**
Solution 2: $Im(y_S) = (-0.519) + (1.928) = 1.409$; $\theta_{S1} = 175.2°$; $\theta_{P2} = 54.6°$; $\theta_{S4} = 59.0°$; **or**
Solution 3: $Im(y_S) = (0.519) + (-1.928) = -1.409$; $\theta_{S2} = 70.6°$; $\theta_{P3} = 125.4°$; $\theta_{S3} = 13.0°$; **or**
Solution 4: $Im(y_S) = (0.519) + (1.928) = 2.446$; $\theta_{S2} = 70.6°$; $\theta_{P4} = 67.8°$; $\theta_{S4} = 59.0°$;
f) Schematic drawing, “T” shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 18

1. $z = 1.170 + j\cdot 0.870$; $Y = 1 / 50\Omega / (1.170 + j\cdot 0.870) = 0.0110S + j\cdot(-0.0082)S$; $\Gamma = (z-1)/(z+1) = (1.170 + j\cdot 0.870-1)/(1.170 + j\cdot 0.870+1) = 0.206+j\cdot(0.318) = 0.379\angle 57.1°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.091$, $Z_{0E} = 54.788\Omega$, $Z_{0O} = 45.630\Omega$
b) Pc = 147.0μW = -8.327dBm ; Pin = Pc + C = -8.327dBm + 20.8dB = 12.473dBm = 17.673 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 17.673mW – 0.1470mW – 0 = 17.526 **mW** = 12.437 **dBm**



3. The shunt RL load with R = 29Ω and L = 1.240nH has $Z_L = 24.84\Omega + j\cdot(10.16)\Omega$ at 9.1GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0\cdot\tan(\beta l)}{Z_0 + j\cdot Z_L\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot\cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 2/5)=-0.727$; $\cot(\beta l)= -1.376$; $Z_{in} = 27.24\Omega\angle -23.2° = 25.04\Omega + j\cdot(-10.73)\Omega$;

b) If the line becomes open-circuited $Z_L = \infty$; $Z_{in} = j\cdot(61.94)\Omega$

4. a) $G = G_1 + G_2 + G_3$ = 16dB + 12dB + 12dB = 40dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.49dB=1.774, G_1 = 16dB=39.811, F_2 = 2.12dB=1.629, G_2 = 12dB=15.849, F_3 = 2.46dB=1.762,
F = 1.774 + (1.629−1)/39.811 + (1.762−1)/39.811/15.849 = 1.791 = 2.531dB

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

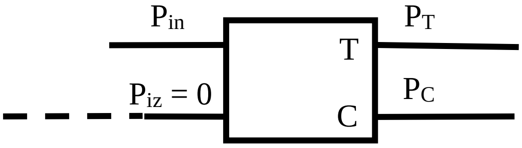
	Δ	|Δ|	K	μ'
T1	-0.422+ j·(0.224)	0.478	0.820	0.853
T2	-0.220+ j·(-0.089)	0.237	0.955	0.979

b) μ' (T1) < μ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2) = 0.050$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}|$ = 23.091 = 13.634 dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.102$, $\arg(S_{22}^*) = 164.3°$; $\theta_{S1} = 145.8°$; $Im(y_S) = -0.205$; **or** $\theta_{S2} = 49.9°$; $Im(y_S) = 0.205$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.616$, $\arg(S_{11}^*) = 141.2°$; $\theta_{S3} = 173.4°$; $Im(y_S) = -1.564$; **or** $\theta_{S4} = 45.4°$; $Im(y_S) = 1.564$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.205) + (-1.564) = -1.769$; $\theta_{S1} = 145.8°$; $\theta_{P1} = 119.5°$; $\theta_{S3} = 173.4°$; **or**
Solution 2: $Im(y_S) = (-0.205) + (1.564) = 1.359$; $\theta_{S1} = 145.8°$; $\theta_{P2} = 53.7°$; $\theta_{S4} = 45.4°$; **or**
Solution 3: $Im(y_S) = (0.205) + (-1.564) = -1.359$; $\theta_{S2} = 49.9°$; $\theta_{P3} = 126.3°$; $\theta_{S3} = 173.4°$; **or**
Solution 4: $Im(y_S) = (0.205) + (1.564) = 1.769$; $\theta_{S2} = 49.9°$; $\theta_{P4} = 60.5°$; $\theta_{S4} = 45.4°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 19

1. $z = 0.795 + j\cdot 1.145$; $Y = 1 / 50\Omega / (0.795 + j\cdot 1.145) = 0.0082S + j\cdot(-0.0118)S$; $\Gamma = (z-1)/(z+1) = (0.795 + j\cdot 1.145-1)/(0.795 + j\cdot 1.145+1) = 0.208+j\cdot(0.505) = 0.546\angle 67.6°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.094$, $Z_{0E} = 54.966\Omega$, $Z_{0O} = 45.483\Omega$
b) Pc = 131.5μW = -8.811dBm ; Pin = Pc + C = -8.811dBm + 20.5dB = 11.689dBm = 14.755 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 14.755mW – 0.1315mW – 0 = 14.623 **mW** = 11.650 **dBm**



3. The series RC load with R = 30Ω and C = 0.454pF has $Z_L = 30.00\Omega + j\cdot(-45.53)\Omega$ at 7.7GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0\cdot\tan(\beta l)}{Z_0 + j\cdot Z_L\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot\cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 7/8)=-1.000$; $\cot(\beta l)= -1.000$; $Z_{in} = 215.81\Omega\angle -24.6° = 196.14\Omega + j\cdot(-90.00)\Omega$;

b) If the line becomes short-circuited $Z_L = 0$; $Z_{in} = j\cdot(-70.00)\Omega$

4. a) $G = G_1 + G_2 + G_3 = 11dB + 18dB + 10dB = 39dB$
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
$F_1 = 2.04dB=1.600$, $G_1 = 11dB=12.589$, $F_2 = 2.58dB=1.811$, $G_2 = 18dB=63.096$, $F_3 = 2.15dB=1.641$,
$F = 1.600 + (1.811-1)/12.589 + (1.641-1)/12.589/63.096 = 1.665 = 2.214dB$

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

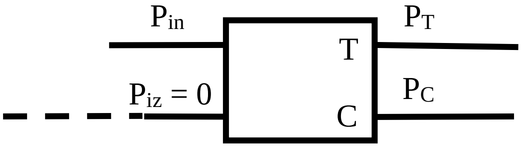
	Δ	|Δ|	K	μ'
T1	-0.480+ j·(0.016)	0.480	0.720	0.794
T2	-0.232+ j·(-0.193)	0.302	0.845	0.926

b) μ' (T1) < μ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2) = 0.120$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 24.944 = 13.970$ dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.186$, $\arg(S_{22}^*) = 131.2°$; $\theta_{S1} = 164.7°$; $Im(y_S) = -0.379$; **or** $\theta_{S2} = 64.0°$; $Im(y_S) = 0.379$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.652$, $\arg(S_{11}^*) = 122.0°$; $\theta_{S3} = 4.3°$; $Im(y_S) = -1.720$; **or** $\theta_{S4} = 53.7°$; $Im(y_S) = 1.720$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.379) + (-1.720) = -2.098$; $\theta_{S1} = 164.7°$; $\theta_{P1} = 115.5°$; $\theta_{S3} = 4.3°$; **or**
Solution 2: $Im(y_S) = (-0.379) + (1.720) = 1.341$; $\theta_{S1} = 164.7°$; $\theta_{P2} = 53.3°$; $\theta_{S4} = 53.7°$; **or**
Solution 3: $Im(y_S) = (0.379) + (-1.720) = -1.341$; $\theta_{S2} = 64.0°$; $\theta_{P3} = 126.7°$; $\theta_{S3} = 4.3°$; **or**
Solution 4: $Im(y_S) = (0.379) + (1.720) = 2.098$; $\theta_{S2} = 64.0°$; $\theta_{P4} = 64.5°$; $\theta_{S4} = 53.7°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 20

1. $z = 1.070 + j\cdot 1.035$; $Y = 1 / 50\Omega / (1.070 + j\cdot 1.035) = 0.0097S + j\cdot(-0.0093)S$; $\Gamma = (z-1)/(z+1) = (1.070 + j\cdot 1.035-1)/(1.070 + j\cdot 1.035+1) = 0.227+j\cdot(0.386) = 0.448\angle 59.6°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.107$, $Z_{0E} = 55.678\Omega$, $Z_{0O} = 44.901\Omega$
b) $P_c = 140.5\mu W = -8.523dBm$; $P_{in} = P_c + C = -8.523dBm + 19.4dB = 10.877dBm = 12.237$ **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 12.237mW – 0.1405mW – 0 = 12.097 **mW** = 10.827 **dBm**



3. The shunt RC load with $R = 57\Omega$ and $C = 0.281pF$ has $Z_L = 32.91\Omega + j\cdot(-28.16)\Omega$ at 8.5GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot \tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 2/6)=-1.732$; $\cot(\beta l)= -0.577$; $Z_{in} = 158.49\Omega\angle -2.7° = 158.31\Omega + j\cdot(-7.55)\Omega$;

b) If the line becomes short-circuited $Z_L = 0$; $Z_{in} = j\cdot(-112.58)\Omega$

4. a) $G = G_1 + G_2 + G_3 = 14dB + 14dB + 14dB = 42dB$
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
$F_1 = 2.28dB=1.690$, $G_1 = 14dB=25.119$, $F_2 = 2.82dB=1.914$, $G_2 = 14dB=25.119$, $F_3 = 2.26dB=1.683$,
$F = 1.690 + (1.914-1)/25.119 + (1.683-1)/25.119/25.119 = 1.728 = 2.375dB$

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

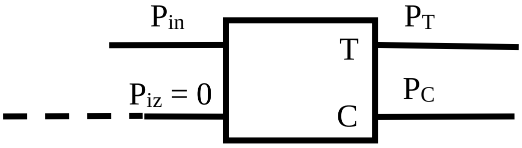
	Δ	|Δ|	K	μ'
T1	-0.385+ j·(0.282)	0.477	0.843	0.869
T2	-0.208+ j·(-0.064)	0.218	0.993	0.997

b) μ' (T1) < μ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2) /(1-|S_{22}|^2) = 0.040$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 22.691 = 13.559$ dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.086$, $\arg(S_{22}^*) = -179.1°$; $\theta_{S1} = 137.0°$; $Im(y_S) = -0.173$; **or** $\theta_{S2} = 42.1°$; $Im(y_S) = 0.173$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.607$, $\arg(S_{11}^*) = 147.0°$; $\theta_{S3} = 170.2°$; $Im(y_S) = -1.528$; **or** $\theta_{S4} = 42.8°$; $Im(y_S) = 1.528$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.173) + (-1.528) = -1.700$; $\theta_{S1} = 137.0°$; $\theta_{P1} = 120.5°$; $\theta_{S3} = 170.2°$; **or**
Solution 2: $Im(y_S) = (-0.173) + (1.528) = 1.355$; $\theta_{S1} = 137.0°$; $\theta_{P2} = 53.6°$; $\theta_{S4} = 42.8°$; **or**
Solution 3: $Im(y_S) = (0.173) + (-1.528) = -1.355$; $\theta_{S2} = 42.1°$; $\theta_{P3} = 126.4°$; $\theta_{S3} = 170.2°$; **or**
Solution 4: $Im(y_S) = (0.173) + (1.528) = 1.700$; $\theta_{S2} = 42.1°$; $\theta_{P4} = 59.5°$; $\theta_{S4} = 42.8°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 21

1. $z = 0.935 + j\cdot 1.265$; $Y = 1 / 50\Omega / (0.935 + j\cdot 1.265) = 0.0076S + j\cdot(-0.0102)S$; $\Gamma = (z-1)/(z+1) = (0.935 + j\cdot 1.265-1)/(0.935 + j\cdot 1.265+1) = 0.276+j\cdot(0.473) = 0.548\angle 59.8°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.079$, $Z_{0E} = 54.143\Omega$, $Z_{0O} = 46.174\Omega$
b) Pc = 80.0μW = -10.969dBm ; Pin = Pc + C = -10.969dBm + 22.0dB = 11.031dBm = 12.679 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 12.679mW – 0.0800mW – 0 = 12.599 **mW** = 11.003 **dBm**



3. The shunt RC load with R = 62Ω and C = 0.304pF has $Z_L = 28.02\Omega + j\cdot(-30.86)\Omega$ at 9.3GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0\cdot\tan(\beta l)}{Z_0 + j\cdot Z_L\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot\cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 6/8)=\infty$; $\cot(\beta l)= 0.000$; $Z_{in} = 59.98\Omega\angle 47.8° = 40.32\Omega + j\cdot(44.41)\Omega$;

b) If the line becomes open-circuited $Z_L = \infty$; $Z_{in} = j\cdot(0.00)\Omega$

4. a) $G = G_1 + G_2 + G_3$ = 11dB + 13dB + 11dB = 35dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.26dB=1.683, G_1 = 11dB=12.589, F_2 = 2.41dB=1.742, G_2 = 13dB=19.953, F_3 = 2.30dB=1.698,
F = 1.683 + (1.742−1)/12.589 + (1.698−1)/12.589/19.953 = 1.744 = 2.416dB

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

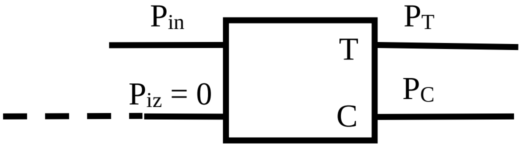
	Δ	|Δ|	K	μ'
T1	-0.352+ j·(-0.344)	0.493	0.561	0.736
T2	-0.144+ j·(-0.387)	0.413	0.662	0.858

b) μ' (T1) < μ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2)$ = 0.332 (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}|$ = 31.978 = 15.049 dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.315$, $\arg(S_{22}^*) = 94.1°$; $\theta_{S1} = 7.2°$; $Im(y_S) = -0.664$; **or** $\theta_{S2} = 78.8°$; $Im(y_S) = 0.664$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.756$, $\arg(S_{11}^*) = 90.0°$; $\theta_{S3} = 24.6°$; $Im(y_S) = -2.310$; **or** $\theta_{S4} = 65.4°$; $Im(y_S) = 2.310$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.664) + (-2.310) = -2.974$; $\theta_{S1} = 7.2°$; $\theta_{P1} = 108.6°$; $\theta_{S3} = 24.6°$; **or**
Solution 2: $Im(y_S) = (-0.664) + (2.310) = 1.646$; $\theta_{S1} = 7.2°$; $\theta_{P2} = 58.7°$; $\theta_{S4} = 65.4°$; **or**
Solution 3: $Im(y_S) = (0.664) + (-2.310) = -1.646$; $\theta_{S2} = 78.8°$; $\theta_{P3} = 121.3°$; $\theta_{S3} = 24.6°$; **or**
Solution 4: $Im(y_S) = (0.664) + (2.310) = 2.974$; $\theta_{S2} = 78.8°$; $\theta_{P4} = 71.4°$; $\theta_{S4} = 65.4°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 22

1. z = 1.280 − j·1.020; Y = 1 / 50Ω / (1.280 − j·1.020) = 0.0096S + j·(0.0076)S ; Γ = (z-1)/(z+1) = (1.280 − j·1.020-1)/(1.280 − j·1.020+1) = 0.269+j·(-0.327) = 0.423∠-50.5°, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20}$ = 0.124, Z_{0E} = 56.663Ω, Z_{0O} = 44.120Ω
b) Pc = 75.5μW = -11.221dBm ; Pin = Pc + C = -11.221dBm + 18.1dB = 6.879dBm = 4.875 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 4.875mW – 0.0755mW – 0 = 4.799 **mW** = 6.812 **dBm**



3. The shunt RL load with R = 38Ω and L = 1.202nH has Z_L = 29.94Ω + j·(15.53)Ω at 9.7GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) tan(βl)=tan(2·π·4/6)=1.732 ; cot(βl)= 0.577 ; Z_{in} = 202.60Ω∠43.3° = 147.53Ω + j·(138.86)Ω ;

b) If the line becomes open-circuited Z_L = ∞ ; Z_{in} = j·(-54.85)Ω

4. a) G = $G_1 + G_2 + G_3$ = 11dB + 17dB + 14dB = 42dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.79dB=1.901, G_1 = 11dB=12.589, F_2 = 2.72dB=1.871, G_2 = 17dB=50.119, F_3 = 2.71dB=1.866,
F = 1.901 + (1.871−1)/12.589 + (1.866−1)/12.589/50.119 = 1.972 = 2.948dB

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

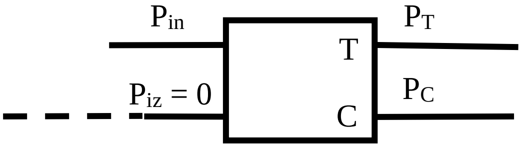
	Δ	|Δ|	K	μ
T1	-0.401+ j·(0.265)	0.481	0.844	0.750
T2	-0.213+ j·(-0.072)	0.225	0.981	0.985

b) μ (T1) < μ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2)$ = 0.040 (L9/2023, S101)
d) For T2: MSG = $|S_{21}| / |S_{12}|$ = 22.818 = 13.583 dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}|$ = 0.086, arg(S_{22}^*) = 171.3° ; θ_{S1} = 141.8° ; Im(y_S) = -0.173 ; **or** θ_{S2} = 46.9° ; Im(y_S) = 0.173
S_{11}^* for T2: 2 solutions for the match, $|S_{11}|$ = 0.610, arg(S_{11}^*) = 145.0° ; θ_{S3} = 171.3° ; Im(y_S) = -1.540 ; **or** θ_{S4} = 43.7° ; Im(y_S) = 1.540
Combining the two schematics(L13/2023, S96), all lines with Z_0 = 50Ω:
Solution 1: Im(y_S) = (-0.173) + (-1.540) = -1.712; θ_{S1} = 141.8° ; θ_{P1} = 120.3° ; θ_{S3} = 171.3° ; **or**
Solution 2: Im(y_S) = (-0.173) + (1.540) = 1.367; θ_{S1} = 141.8° ; θ_{P2} = 53.8° ; θ_{S4} = 43.7° ; **or**
Solution 3: Im(y_S) = (0.173) + (-1.540) = -1.367; θ_{S2} = 46.9° ; θ_{P3} = 126.2° ; θ_{S3} = 171.3° ; **or**
Solution 4: Im(y_S) = (0.173) + (1.540) = 1.712; θ_{S2} = 46.9° ; θ_{P4} = 59.7° ; θ_{S4} = 43.7° ;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 23

1. $z = 0.725 - j\cdot 1.165$; $Y = 1 / 50\Omega / (0.725 - j\cdot 1.165) = 0.0077S + j\cdot(0.0124)S$; $\Gamma = (z-1)/(z+1) = (0.725 - j\cdot 1.165-1)/(0.725 - j\cdot 1.165+1) = 0.204+j\cdot(-0.538) = 0.575\angle -69.2°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.075$, $Z_{0E} = 53.901\Omega$, $Z_{0O} = 46.381\Omega$
b) $P_c = 68.5\mu W = -11.643dBm$; $P_{in} = P_c + C = -11.643dBm + 22.5dB = 10.857dBm = 12.181$ **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = $P_{in} - P_c - P_{iz} = 12.181mW - 0.0685mW - 0 = 12.113$ **mW** = 10.832 **dBm**



3. The series RL load with R = 47Ω and L = 1.369nH has $Z_L = 47.00\Omega + j\cdot(67.95)\Omega$ at 7.9GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot \tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 2/5)=-0.727$; $\cot(\beta l)= -1.376$; $Z_{in} = 26.96\Omega\angle 52.9° = 16.26\Omega + j\cdot(21.50)\Omega$;

b) If the line becomes open-circuited $Z_L = \infty$; $Z_{in} = j\cdot(68.82)\Omega$

4. a) $G = G_1 + G_2 + G_3 = 17dB + 12dB + 11dB = 40dB$
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
$F_1 = 2.76dB=1.888$, $G_1 = 17dB=50.119$, $F_2 = 2.49dB=1.774$, $G_2 = 12dB=15.849$, $F_3 = 2.87dB=1.936$,
$F = 1.888 + (1.774-1)/50.119 + (1.936-1)/50.119/15.849 = 1.905 = 2.798dB$

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

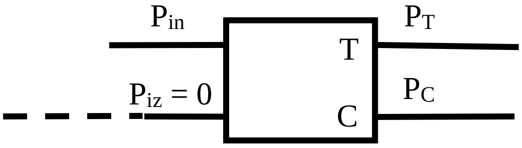
	Δ	|Δ|	K	μ'
T1	-0.204+ j·(0.442)	0.487	0.905	0.916
T2	-0.158+ j·(-0.010)	0.158	1.125	1.056

b) μ' (T1) < μ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2) /(1-|S_{22}|^2) = 0.040$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 21.400 = 13.304$ dB (L9/2023, S75) ; However K = 1.125 > 1 so maximum gain is $MAG = |S_{21}| / |S_{12}| \cdot [K - \sqrt{(K^2 - 1)}] = 13.035 = 11.151$ dB (L9/2023, S76)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.098$, $\arg(S_{22}^*) = -88.7°$; $\theta_{S1} = 92.2°$; $Im(y_S) = -0.197$; **or** $\theta_{S2} = 176.5°$; $Im(y_S) = 0.197$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.579$, $\arg(S_{11}^*) = 167.0°$; $\theta_{S3} = 159.2°$; $Im(y_S) = -1.420$; **or** $\theta_{S4} = 33.8°$; $Im(y_S) = 1.420$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.197) + (-1.420) = -1.617$; $\theta_{S1} = 92.2°$; $\theta_{P1} = 121.7°$; $\theta_{S3} = 159.2°$; **or**
Solution 2: $Im(y_S) = (-0.197) + (1.420) = 1.223$; $\theta_{S1} = 92.2°$; $\theta_{P2} = 50.7°$; $\theta_{S4} = 33.8°$; **or**
Solution 3: $Im(y_S) = (0.197) + (-1.420) = -1.223$; $\theta_{S2} = 176.5°$; $\theta_{P3} = 129.3°$; $\theta_{S3} = 159.2°$; **or**
Solution 4: $Im(y_S) = (0.197) + (1.420) = 1.617$; $\theta_{S2} = 176.5°$; $\theta_{P4} = 58.3°$; $\theta_{S4} = 33.8°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 24

1. z = 0.865 + j·1.175; Y = 1 / 50Ω / (0.865 + j·1.175) = 0.0081S + j·(-0.0110)S ; Γ = (z-1)/(z+1) = (0.865 + j·1.175-1)/(0.865 + j·1.175+1) = 0.232+j·(0.484) = 0.537∠64.3°, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20}$ = 0.107, Z_{0E} = 55.678Ω, Z_{0O} = 44.901Ω
b) Pc = 90.0μW = -10.458dBm ; Pin = Pc + C = -10.458dBm + 19.4dB = 8.942dBm = 7.839 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 7.839mW – 0.0900mW – 0 = 7.749 **mW** = 8.892 **dBm**



3. The shunt RC load with R = 68Ω and C = 0.320pF has Z_L = 24.33Ω + j·(-32.59)Ω at 9.8GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot\cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) tan(βl)=tan(2·π·4/8)=0.000 ; cot(βl)= ∞ ; Z_{in} = 40.67Ω∠-53.3° = 24.33Ω + j·(-32.59)Ω ;

b) If the line becomes short-circuited Z_L = 0 ; Z_{in} = j·(0.00)Ω

4. a) G = $G_1 + G_2 + G_3$ = 10dB + 14dB + 13dB = 37dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.71dB=1.866, G_1 = 10dB=10.000, F_2 = 2.64dB=1.837, G_2 = 14dB=25.119, F_3 = 2.88dB=1.941,
F = 1.866 + (1.837−1)/10.000 + (1.941−1)/10.000/25.119 = 1.954 = 2.909dB

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

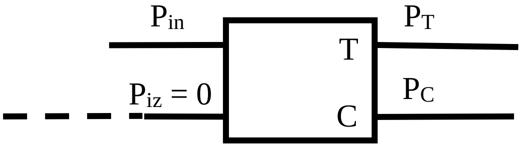
	Δ	|Δ|	K	μ'
T1	-0.479+ j·(0.041)	0.480	0.733	0.801
T2	-0.233+ j·(-0.183)	0.297	0.856	0.931

b) μ' (T1) < μ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2)$ = 0.110 (L9/2023, S101)
d) For T2: MSG = $|S_{21}| / |S_{12}|$ = 24.560 = 13.902 dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}|$ = 0.176, $\arg(S_{22}^*)$ = 133.7° ; θ_{S1} = 163.2° ; $\text{Im}(y_S)$ = -0.358 ; **or** θ_{S2} = 63.1° ; $\text{Im}(y_S)$ = 0.358
S_{11}^* for T2: 2 solutions for the match, $|S_{11}|$ = 0.646, $\arg(S_{11}^*)$ = 124.0° ; θ_{S3} = 3.1° ; $\text{Im}(y_S)$ = -1.693 ; **or** θ_{S4} = 52.9° ; $\text{Im}(y_S)$ = 1.693
Combining the two schematics(L13/2023, S96), all lines with Z_0 = 50Ω:
Solution 1: $\text{Im}(y_S)$ = (-0.358) + (-1.693) = -2.050; θ_{S1} = 163.2° ; θ_{P1} = 116.0° ; θ_{S3} = 3.1° ; **or**
Solution 2: $\text{Im}(y_S)$ = (-0.358) + (1.693) = 1.335; θ_{S1} = 163.2° ; θ_{P2} = 53.2° ; θ_{S4} = 52.9° ; **or**
Solution 3: $\text{Im}(y_S)$ = (0.358) + (-1.693) = -1.335; θ_{S2} = 63.1° ; θ_{P3} = 126.8° ; θ_{S3} = 3.1° ; **or**
Solution 4: $\text{Im}(y_S)$ = (0.358) + (1.693) = 2.050; θ_{S2} = 63.1° ; θ_{P4} = 64.0° ; θ_{S4} = 52.9° ;
f) Schematic drawing, “T” shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 25

1. $z = 0.875 + j\cdot0.990$; $Y = 1 / 50\Omega / (0.875 + j\cdot0.990) = 0.0100S + j\cdot(-0.0113)S$; $\Gamma = (z-1)/(z+1) = (0.875 + j\cdot0.990-1)/(0.875 + j\cdot0.990+1) = 0.166+j\cdot(0.440) = 0.471\angle69.4°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.105$, $Z_{0E} = 55.541\Omega$, $Z_{0O} = 45.012\Omega$
b) $P_c = 79.5\mu W = -10.996dBm$; $P_{in} = P_c + C = -10.996dBm + 19.6dB = 8.604dBm = 7.250$ **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = $P_{in} - P_c - P_{iz} = 7.250mW - 0.0795mW - 0 = 7.171$ **mW** = 8.556 **dBm**



3. The series RC load with $R = 39\Omega$ and $C = 0.598pF$ has $Z_L = 39.00\Omega + j\cdot(-36.46)\Omega$ at 7.3GHz

$Z_{in} = Z_0 \cdot \frac{Z_L+j\cdot Z_0\cdot\tan(\beta l)}{Z_0+j\cdot Z_L\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0+j\cdot\tan(\beta l)}{1+j\cdot Z_L/Z_0\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot\cot(\beta l)+j}{\cot(\beta l)+j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot3/6)=0.000$; $\cot(\beta l)= \infty$; $Z_{in} = 53.39\Omega\angle-43.1° = 39.00\Omega + j\cdot(-36.46)\Omega$;

b) If the line becomes open-circuited $Z_L = \infty$; $Z_{in} = j\cdot(0.00)\Omega$

4. a) $G = G_1 + G_2 + G_3 = 14dB + 16dB + 15dB = 45dB$
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
$F_1 = 2.55dB=1.799$, $G_1 = 14dB=25.119$, $F_2 = 2.19dB=1.656$, $G_2 = 16dB=39.811$, $F_3 = 2.12dB=1.629$,
$F = 1.799 + (1.656-1)/25.119 + (1.629-1)/25.119/39.811 = 1.826 = 2.614dB$

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

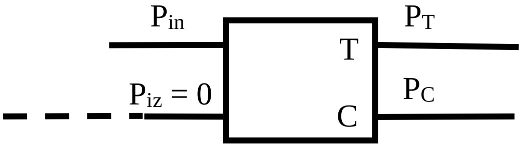
	Δ	|Δ|	K	μ'
T1	-0.320+ j·(0.347)	0.473	0.857	0.879
T2	-0.189+ j·(-0.037)	0.192	1.044	1.020

b) μ' (T1) < μ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2) /(1-|S_{22}|^2) = 0.038$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 22.182 = 13.460$ dB (L9/2023, S75) ; However $K = 1.044 > 1$ so maximum gain is $MAG = |S_{21}| / |S_{12}| \cdot [K - \sqrt{(K^2 - 1)}] = 16.495 = 12.173$ dB (L9/2023, S76)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.087$, $\arg(S_{22}^*) = -140.8°$; $\theta_{S1} = 117.9°$; $Im(y_S) = -0.175$; **or** $\theta_{S2} = 22.9°$; $Im(y_S) = 0.175$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.595$, $\arg(S_{11}^*) = 155.0°$; $\theta_{S3} = 165.8°$; $Im(y_S) = -1.481$; **or** $\theta_{S4} = 39.2°$; $Im(y_S) = 1.481$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.175) + (-1.481) = -1.655$; $\theta_{S1} = 117.9°$; $\theta_{P1} = 121.1°$; $\theta_{S3} = 165.8°$; **or**
Solution 2: $Im(y_S) = (-0.175) + (1.481) = 1.306$; $\theta_{S1} = 117.9°$; $\theta_{P2} = 52.6°$; $\theta_{S4} = 39.2°$; **or**
Solution 3: $Im(y_S) = (0.175) + (-1.481) = -1.306$; $\theta_{S2} = 22.9°$; $\theta_{P3} = 127.4°$; $\theta_{S3} = 165.8°$; **or**
Solution 4: $Im(y_S) = (0.175) + (1.481) = 1.655$; $\theta_{S2} = 22.9°$; $\theta_{P4} = 58.9°$; $\theta_{S4} = 39.2°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 26

1. $z = 0.995 + j\cdot 1.025$; $Y = 1 / 50\Omega / (0.995 + j\cdot 1.025) = 0.0098S + j\cdot(-0.0100)S$; $\Gamma = (z-1)/(z+1) = (0.995 + j\cdot 1.025-1)/(0.995 + j\cdot 1.025+1) = 0.207+j\cdot(0.408) = 0.457\angle 63.1°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.102$, $Z_{0E} = 55.407\Omega$, $Z_{0O} = 45.120\Omega$
b) Pc = 112.5µW = -9.488dBm ; Pin = Pc + C = -9.488dBm + 19.8dB = 10.312dBm = 10.744 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 10.744mW – 0.1125mW – 0 = 10.631 **mW** = 10.266 **dBm**



3. The shunt RL load with R = 45Ω and L = 0.507nH has $Z_L = 14.62\Omega + j\cdot(21.08)\Omega$ at 9.8GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0\cdot\tan(\beta l)}{Z_0 + j\cdot Z_L\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot\cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 3/5)=0.727$; $\cot(\beta l)= 1.376$; $Z_{in} = 84.02\Omega\angle 61.5° = 40.03\Omega + j\cdot(73.87)\Omega$;

b) If the line becomes short-circuited $Z_L = 0$; $Z_{in} = j\cdot(39.96)\Omega$

4. a) $G = G_1 + G_2 + G_3$ = 10dB + 15dB + 15dB = 40dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.71dB=1.866, G_1 = 10dB=10.000, F_2 = 2.29dB=1.694, G_2 = 15dB=31.623, F_3 = 2.39dB=1.734,
F = 1.866 + (1.694−1)/10.000 + (1.734−1)/10.000/31.623 = 1.938 = 2.874dB

5. a) Must compute either µ or µ' (**as requested!**) (L8/2023, S96 or 97);

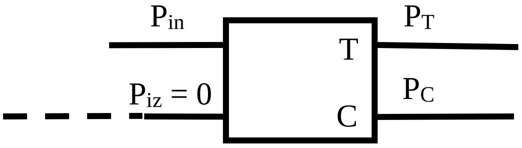
	Δ	|Δ|	K	µ
T1	-0.249+ j·(0.415)	0.484	0.892	0.820
T2	-0.169+ j·(-0.018)	0.170	1.101	1.076

b) µ (T1) < µ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2) = 0.037$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}|$ = 21.673 = 13.359 dB (L9/2023, S75) ; However K = 1.101 > 1 so maximum gain is $MAG = |S_{21}| / |S_{12}| \cdot [K - \sqrt{(K^2 - 1)}]$ = 13.884 = 11.425 dB (L9/2023, S76)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.088$, $\arg(S_{22}^*) = -102.5°$; $\theta_{S1} = 98.8°$; $Im(y_S) = -0.177$; **or** $\theta_{S2} = 3.7°$; $Im(y_S) = 0.177$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.583$, $\arg(S_{11}^*) = 163.0°$; $\theta_{S3} = 161.3°$; $Im(y_S) = -1.435$; **or** $\theta_{S4} = 35.7°$; $Im(y_S) = 1.435$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.177) + (-1.435) = -1.612$; $\theta_{S1} = 98.8°$; $\theta_{P1} = 121.8°$; $\theta_{S3} = 161.3°$; **or**
Solution 2: $Im(y_S) = (-0.177) + (1.435) = 1.258$; $\theta_{S1} = 98.8°$; $\theta_{P2} = 51.5°$; $\theta_{S4} = 35.7°$; **or**
Solution 3: $Im(y_S) = (0.177) + (-1.435) = -1.258$; $\theta_{S2} = 3.7°$; $\theta_{P3} = 128.5°$; $\theta_{S3} = 161.3°$; **or**
Solution 4: $Im(y_S) = (0.177) + (1.435) = 1.612$; $\theta_{S2} = 3.7°$; $\theta_{P4} = 58.2°$; $\theta_{S4} = 35.7°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 27

1. $z = 0.965 + j\cdot0.995$; $Y = 1 / 50\Omega / (0.965 + j\cdot0.995) = 0.0100S + j\cdot(-0.0104)S$; $\Gamma = (z-1)/(z+1) = (0.965 + j\cdot0.995-1)/(0.965 + j\cdot0.995+1) = 0.190+j\cdot(0.410) = 0.452\angle65.2°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.136$, $Z_{0E} = 57.359\Omega$, $Z_{0O} = 43.585\Omega$
b) Pc = 146.0µW = -8.356dBm ; Pin = Pc + C = -8.356dBm + 17.3dB = 8.944dBm = 7.841 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 7.841mW – 0.1460mW – 0 = 7.695 **mW** = 8.862 **dBm**



3. The series RL load with R = 55Ω and L = 1.678nH has $Z_L = 55.00\Omega + j\cdot(73.80)\Omega$ at 7.0GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0\cdot\tan(\beta l)}{Z_0 + j\cdot Z_L\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot\cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot7/8)=-1.000$; $\cot(\beta l)= -1.000$; $Z_{in} = 20.43\Omega\angle57.4° = 11.02\Omega + j\cdot(17.21)\Omega$;

b) If the line becomes open-circuited $Z_L = \infty$; $Z_{in} = j\cdot(40.00)\Omega$

4. a) $G = G_1 + G_2 + G_3$ = 14dB + 10dB + 17dB = 41dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.23dB=1.671, G_1 = 14dB=25.119, F_2 = 2.18dB=1.652, G_2 = 10dB=10.000, F_3 = 2.97dB=1.982,
F = 1.671 + (1.652−1)/25.119 + (1.982−1)/25.119/10.000 = 1.701 = 2.307dB

5. a) Must compute either µ or µ' (**as requested!**) (L8/2023, S96 or 97);

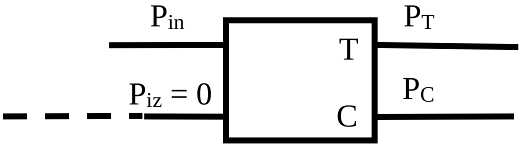
	Δ	|Δ|	K	µ'
T1	-0.430+ j·(0.204)	0.476	0.810	0.848
T2	-0.223+ j·(-0.098)	0.243	0.943	0.973

b) µ' (T1) < µ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2)$ = 0.055 (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}|$ = 23.227 = 13.660 dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.110$, $\arg(S_{22}^*) = 160.7°$; $\theta_{S1} = 147.8°$; $Im(y_S) = -0.221$; **or** $\theta_{S2} = 51.5°$; $Im(y_S) = 0.221$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.619$, $\arg(S_{11}^*) = 139.3°$; $\theta_{S3} = 174.5°$; $Im(y_S) = -1.576$; **or** $\theta_{S4} = 46.2°$; $Im(y_S) = 1.576$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.221) + (-1.576) = -1.798$; $\theta_{S1} = 147.8°$; $\theta_{P1} = 119.1°$; $\theta_{S3} = 174.5°$; **or**
Solution 2: $Im(y_S) = (-0.221) + (1.576) = 1.355$; $\theta_{S1} = 147.8°$; $\theta_{P2} = 53.6°$; $\theta_{S4} = 46.2°$; **or**
Solution 3: $Im(y_S) = (0.221) + (-1.576) = -1.355$; $\theta_{S2} = 51.5°$; $\theta_{P3} = 126.4°$; $\theta_{S3} = 174.5°$; **or**
Solution 4: $Im(y_S) = (0.221) + (1.576) = 1.798$; $\theta_{S2} = 51.5°$; $\theta_{P4} = 60.9°$; $\theta_{S4} = 46.2°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 28

1. $z = 1.095 + j\cdot1.045$; $Y = 1 / 50\Omega / (1.095 + j\cdot1.045) = 0.0096S + j\cdot(-0.0091)S$; $\Gamma = (z-1)/(z+1) = (1.095 + j\cdot1.045-1)/(1.095 + j\cdot1.045+1) = 0.236+j\cdot(0.381) = 0.448\angle58.3°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.133$, $Z_{0E} = 57.178\Omega$, $Z_{0O} = 43.723\Omega$
b) $P_c = 104.0\mu W = -9.830dBm$; $P_{in} = P_c + C = -9.830dBm + 17.5dB = 7.670dBm = 5.848$ **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 5.848mW – 0.1040mW – 0 = 5.744 **mW** = 7.592 **dBm**



3. The series RL load with R = 71Ω and L = 1.417nH has $Z_L = 71.00\Omega + j\cdot(66.77)\Omega$ at 7.5GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0\cdot\tan(\beta l)}{Z_0 + j\cdot Z_L\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot\cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot6/8)=\infty$; $\cot(\beta l)= 0.000$; $Z_{in} = 20.78\Omega\angle-43.2° = 15.13\Omega + j\cdot(-14.23)\Omega$;

b) If the line becomes open-circuited $Z_L = \infty$; $Z_{in} = j\cdot(0.00)\Omega$

4. a) $G = G_1 + G_2 + G_3 = 11dB + 13dB + 18dB = 42dB$
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
$F_1 = 2.41dB=1.742$, $G_1 = 11dB=12.589$, $F_2 = 2.30dB=1.698$, $G_2 = 13dB=19.953$, $F_3 = 2.00dB=1.585$,
$F = 1.742 + (1.698-1)/12.589 + (1.585-1)/12.589/19.953 = 1.800 = 2.552dB$

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

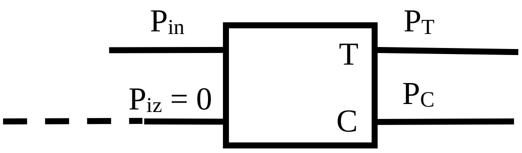
	Δ	|Δ|	K	μ'
T1	-0.228+ j·(0.435)	0.491	0.902	0.912
T2	-0.164+ j·(-0.014)	0.164	1.116	1.052

b) μ' (T1) < μ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2) = 0.036$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 21.545 = 13.334$ dB (L9/2023, S75) ; However K = 1.116 > 1 so maximum gain is $MAG = |S_{21}| / |S_{12}| \cdot [K - \sqrt{(K^2 - 1)}] = 13.378 = 11.264$ dB (L9/2023, S76)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.088$, $\arg(S_{22}^*) = -92.9°$; $\theta_{S1} = 94.0°$; $Im(y_S) = -0.177$; **or** $\theta_{S2} = 178.9°$; $Im(y_S) = 0.177$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.580$, $\arg(S_{11}^*) = 165.0°$; $\theta_{S3} = 160.2°$; $Im(y_S) = -1.424$; **or** $\theta_{S4} = 34.8°$; $Im(y_S) = 1.424$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.177) + (-1.424) = -1.601$; $\theta_{S1} = 94.0°$; $\theta_{P1} = 122.0°$; $\theta_{S3} = 160.2°$; **or**
Solution 2: $Im(y_S) = (-0.177) + (1.424) = 1.247$; $\theta_{S1} = 94.0°$; $\theta_{P2} = 51.3°$; $\theta_{S4} = 34.8°$; **or**
Solution 3: $Im(y_S) = (0.177) + (-1.424) = -1.247$; $\theta_{S2} = 178.9°$; $\theta_{P3} = 128.7°$; $\theta_{S3} = 160.2°$; **or**
Solution 4: $Im(y_S) = (0.177) + (1.424) = 1.601$; $\theta_{S2} = 178.9°$; $\theta_{P4} = 58.0°$; $\theta_{S4} = 34.8°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 29

1. z = 0.895 + j·1.210; Y = 1 / 50Ω / (0.895 + j·1.210) = 0.0079S + j·(-0.0107)S ; Γ = (z-1)/(z+1) = (0.895 + j·1.210-1)/(0.895 + j·1.210+1) = 0.250+j·(0.479) = 0.540∠62.4°, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20}$ = 0.123, Z_{0E} = 56.581Ω, Z_{0O} = 44.184Ω
b) Pc = 130.0μW = -8.861dBm ; Pin = Pc + C = -8.861dBm + 18.2dB = 9.339dBm = 8.589 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 8.589mW – 0.1300mW – 0 = 8.459 **mW** = 9.273 **dBm**



3. The shunt RC load with R = 37Ω and C = 0.310pF has Z_L = 24.35Ω + j·(-17.55)Ω at 10.0GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) tan(βl)=tan(2·π·6/8)=∞ ; cot(βl)= 0.000 ; Z_{in} = 240.70Ω∠35.8° = 195.27Ω + j·(140.73)Ω ;

b) If the line becomes short-circuited Z_L = 0 ; Z_{in} = j·(0.00)Ω

4. a) G = $G_1 + G_2 + G_3$ = 19dB + 19dB + 17dB = 55dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.30dB=1.698, G_1 = 19dB=79.433, F_2 = 2.67dB=1.849, G_2 = 19dB=79.433, F_3 = 2.50dB=1.778,
F = 1.698 + (1.849−1)/79.433 + (1.778−1)/79.433/79.433 = 1.709 = 2.328dB

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

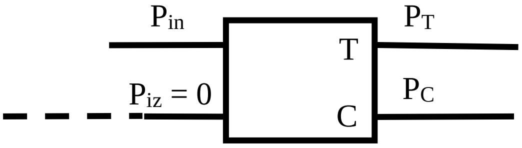
	Δ	|Δ|	K	μ'
T1	-0.157+ j·(0.456)	0.483	0.912	0.923
T2	-0.146+ j·(-0.003)	0.146	1.146	1.065

b) μ' (T1) < μ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2)$ = 0.048 (L9/2023, S101)
d) For T2: MSG = $|S_{21}| / |S_{12}|$ = 21.109 = 13.245 dB (L9/2023, S75) ; However K = 1.146 > 1 so maximum gain is MAG = $|S_{21}| / |S_{12}| \cdot [K - \sqrt{(K^2 - 1)}]$ = 12.380 = 10.927 dB (L9/2023, S76)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}|$ = 0.118, arg(S_{22}^*) = -80.3° ; θ_{S1} = 88.5° ; Im(y_S) = -0.238 ; **or** θ_{S2} = 171.8° ; Im(y_S) = 0.238
S_{11}^* for T2: 2 solutions for the match, $|S_{11}|$ = 0.577, arg(S_{11}^*) = 171.0° ; θ_{S3} = 157.1° ; Im(y_S) = -1.413 ; **or** θ_{S4} = 31.9° ; Im(y_S) = 1.413
Combining the two schematics(L13/2023, S96), all lines with Z_0 = 50Ω:
Solution 1: Im(y_S) = (-0.238) + (-1.413) = -1.651; θ_{S1} = 88.5° ; θ_{P1} = 121.2° ; θ_{S3} = 157.1° ; **or**
Solution 2: Im(y_S) = (-0.238) + (1.413) = 1.175; θ_{S1} = 88.5° ; θ_{P2} = 49.6° ; θ_{S4} = 31.9° ; **or**
Solution 3: Im(y_S) = (0.238) + (-1.413) = -1.175; θ_{S2} = 171.8° ; θ_{P3} = 130.4° ; θ_{S3} = 157.1° ; **or**
Solution 4: Im(y_S) = (0.238) + (1.413) = 1.651; θ_{S2} = 171.8° ; θ_{P4} = 58.8° ; θ_{S4} = 31.9° ;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 30

1. $z = 1.155 + j\cdot 1.110$; $Y = 1 / 50\Omega / (1.155 + j\cdot 1.110) = 0.0090S + j\cdot(-0.0087)S$; $\Gamma = (z-1)/(z+1) = (1.155 + j\cdot 1.110-1)/(1.155 + j\cdot 1.110+1) = 0.267+j\cdot(0.378) = 0.462\angle 54.8°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.117$, $Z_{0E} = 56.264\Omega$, $Z_{0O} = 44.433\Omega$
b) $Pc = 92.5\mu W = -10.339dBm$; $Pin = Pc + C = -10.339dBm + 18.6dB = 8.261dBm = 6.701$ **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 6.701mW – 0.0925mW – 0 = 6.609 **mW** = 8.201 **dBm**



3. The series RC load with $R = 31\Omega$ and $C = 0.402pF$ has $Z_L = 31.00\Omega + j\cdot(-59.99)\Omega$ at 6.6GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0\cdot\tan(\beta l)}{Z_0 + j\cdot Z_L\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot\cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 1/3)=-1.732$; $\cot(\beta l)= -0.577$; $Z_{in} = 202.69\Omega\angle 42.0° = 150.69\Omega + j\cdot(135.55)\Omega$;

b) If the line becomes short-circuited $Z_L = 0$; $Z_{in} = j\cdot(-121.24)\Omega$

4. a) $G = G_1 + G_2 + G_3 = 12dB + 18dB + 18dB = 48dB$
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
$F_1 = 2.46dB=1.762$, $G_1 = 12dB=15.849$, $F_2 = 2.95dB=1.972$, $G_2 = 18dB=63.096$, $F_3 = 2.59dB=1.816$,
$F = 1.762 + (1.972-1)/15.849 + (1.816-1)/15.849/63.096 = 1.824 = 2.611dB$

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

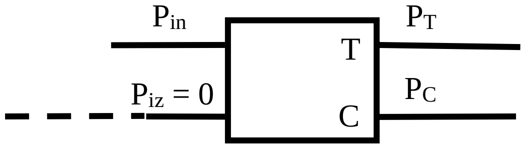
	Δ	|Δ|	K	μ
T1	-0.383+ j·(-0.306)	0.490	0.577	0.455
T2	-0.165+ j·(-0.361)	0.397	0.687	0.746

b) μ (T1) < μ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2) = 0.300$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 31.000 = 14.914$ dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.301$, $\arg(S_{22}^*) = 98.5°$; $\theta_{S1} = 4.5°$; $Im(y_S) = -0.631$; **or** $\theta_{S2} = 77.0°$; $Im(y_S) = 0.631$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.742$, $\arg(S_{11}^*) = 94.0°$; $\theta_{S3} = 22.0°$; $Im(y_S) = -2.214$; **or** $\theta_{S4} = 64.0°$; $Im(y_S) = 2.214$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.631) + (-2.214) = -2.845$; $\theta_{S1} = 4.5°$; $\theta_{P1} = 109.4°$; $\theta_{S3} = 22.0°$; **or**
Solution 2: $Im(y_S) = (-0.631) + (2.214) = 1.582$; $\theta_{S1} = 4.5°$; $\theta_{P2} = 57.7°$; $\theta_{S4} = 64.0°$; **or**
Solution 3: $Im(y_S) = (0.631) + (-2.214) = -1.582$; $\theta_{S2} = 77.0°$; $\theta_{P3} = 122.3°$; $\theta_{S3} = 22.0°$; **or**
Solution 4: $Im(y_S) = (0.631) + (2.214) = 2.845$; $\theta_{S2} = 77.0°$; $\theta_{P4} = 70.6°$; $\theta_{S4} = 64.0°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 31

1. $z = 1.050 - j\cdot 1.165$; $Y = 1 / 50\Omega / (1.050 - j\cdot 1.165) = 0.0085S + j\cdot(0.0095)S$; $\Gamma = (z-1)/(z+1) = (1.050 - j\cdot 1.165-1)/(1.050 - j\cdot 1.165+1) = 0.263+j\cdot(-0.419) = 0.495\angle{-57.9°}$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.104$, $Z_{0E} = 55.474\Omega$, $Z_{0O} = 45.066\Omega$
b) $P_c = 96.5\mu W = -10.155dBm$; $P_{in} = P_c + C = -10.155dBm + 19.7dB = 9.545dBm = 9.006$ **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 9.006mW – 0.0965mW – 0 = 8.909 **mW** = 9.498 **dBm**



3. The shunt RC load with $R = 41\Omega$ and $C = 0.566pF$ has $Z_L = 16.88\Omega + j\cdot(-20.18)\Omega$ at 8.2GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot \tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 2/6)=-1.732$; $\cot(\beta l)= -0.577$; $Z_{in} = 195.20\Omega\angle{-32.9°} = 163.98\Omega + j\cdot(-105.90)\Omega$;

b) If the line becomes open-circuited $Z_L = \infty$; $Z_{in} = j\cdot(34.64)\Omega$

4. a) $G = G_1 + G_2 + G_3 = 14dB + 11dB + 18dB = 43dB$
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
$F_1 = 2.14dB=1.637$, $G_1 = 14dB=25.119$, $F_2 = 2.28dB=1.690$, $G_2 = 11dB=12.589$, $F_3 = 2.92dB=1.959$,
$F = 1.637 + (1.690-1)/25.119 + (1.959-1)/25.119/12.589 = 1.667 = 2.220dB$

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

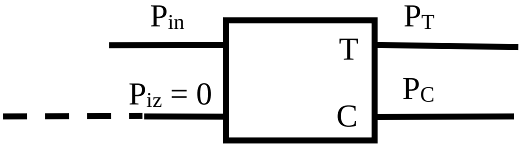
	Δ	|Δ|	K	μ
T1	-0.287+ j·(0.381)	0.476	0.872	0.793
T2	-0.179+ j·(-0.026)	0.181	1.072	1.054

b) μ (T1) < μ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2) /(1-|S_{22}|^2) = 0.037$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 21.927 = 13.410$ dB (L9/2023, S75) ; However K = 1.072 > 1 so maximum gain is $MAG = |S_{21}| / |S_{12}| \cdot [K - \sqrt{(K^2 - 1)}] = 15.041 = 11.773$ dB (L9/2023, S76)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.087$, $\arg(S_{22}^*) = -121.6°$; $\theta_{S1} = 108.3°$; $Im(y_S) = -0.175$; **or** $\theta_{S2} = 13.3°$; $Im(y_S) = 0.175$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.589$, $\arg(S_{11}^*) = 159.0°$; $\theta_{S3} = 163.5°$; $Im(y_S) = -1.458$; **or** $\theta_{S4} = 37.5°$; $Im(y_S) = 1.458$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.175) + (-1.458) = -1.632$; $\theta_{S1} = 108.3°$; $\theta_{P1} = 121.5°$; $\theta_{S3} = 163.5°$; **or**
Solution 2: $Im(y_S) = (-0.175) + (1.458) = 1.283$; $\theta_{S1} = 108.3°$; $\theta_{P2} = 52.1°$; $\theta_{S4} = 37.5°$; **or**
Solution 3: $Im(y_S) = (0.175) + (-1.458) = -1.283$; $\theta_{S2} = 13.3°$; $\theta_{P3} = 127.9°$; $\theta_{S3} = 163.5°$; **or**
Solution 4: $Im(y_S) = (0.175) + (1.458) = 1.632$; $\theta_{S2} = 13.3°$; $\theta_{P4} = 58.5°$; $\theta_{S4} = 37.5°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 32

1. $z = 1.045 - j\cdot 1.035$; $Y = 1 / 50\Omega / (1.045 - j\cdot 1.035) = 0.0097S + j\cdot(0.0096)S$; $\Gamma = (z-1)/(z+1) = (1.045 - j\cdot 1.035-1)/(1.045 - j\cdot 1.035+1) = 0.221+j\cdot(-0.394) = 0.452\angle -60.7°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.111$, $Z_{0E} = 55.891\Omega$, $Z_{0O} = 44.730\Omega$
b) $P_c = 111.5\mu W = -9.527dBm$; $P_{in} = P_c + C = -9.527dBm + 19.1dB = 9.573dBm = 9.063$ **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = $P_{in} - P_c - P_{iz} = 9.063mW - 0.1115mW - 0 = 8.952$ **mW** = 9.519 **dBm**



3. The series RC load with $R = 40\Omega$ and $C = 0.432pF$ has $Z_L = 40.00\Omega + j\cdot(-51.89)\Omega$ at 7.1GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0\cdot\tan(\beta l)}{Z_0 + j\cdot Z_L\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot\cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 3/6)=0.000$; $\cot(\beta l)= \infty$; $Z_{in} = 65.52\Omega\angle -52.4° = 40.00\Omega + j\cdot(-51.89)\Omega$;

b) If the line becomes short-circuited $Z_L = 0$; $Z_{in} = j\cdot(0.00)\Omega$

4. a) $G = G_1 + G_2 + G_3 = 18dB + 15dB + 13dB = 46dB$
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
$F_1 = 2.14dB=1.637$, $G_1 = 18dB=63.096$, $F_2 = 2.92dB=1.959$, $G_2 = 15dB=31.623$, $F_3 = 2.38dB=1.730$,
$F = 1.637 + (1.959-1)/63.096 + (1.730-1)/63.096/31.623 = 1.652 = 2.181dB$

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

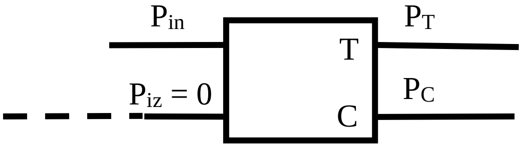
	Δ	|Δ|	K	μ
T1	-0.446+ j·(-0.200)	0.489	0.615	0.490
T2	-0.203+ j·(-0.297)	0.359	0.750	0.800

b) μ (T1) < μ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2) /(1-|S_{22}|^2) = 0.235$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 28.727 = 14.583$ dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.267$, $\arg(S_{22}^*) = 109.6°$; $\theta_{S1} = 178.0°$; $Im(y_S) = -0.554$; **or** $\theta_{S2} = 72.5°$; $Im(y_S) = 0.554$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.707$, $\arg(S_{11}^*) = 104.0°$; $\theta_{S3} = 15.5°$; $Im(y_S) = -1.999$; **or** $\theta_{S4} = 60.5°$; $Im(y_S) = 1.999$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.554) + (-1.999) = -2.554$; $\theta_{S1} = 178.0°$; $\theta_{P1} = 111.4°$; $\theta_{S3} = 15.5°$; **or**
Solution 2: $Im(y_S) = (-0.554) + (1.999) = 1.445$; $\theta_{S1} = 178.0°$; $\theta_{P2} = 55.3°$; $\theta_{S4} = 60.5°$; **or**
Solution 3: $Im(y_S) = (0.554) + (-1.999) = -1.445$; $\theta_{S2} = 72.5°$; $\theta_{P3} = 124.7°$; $\theta_{S3} = 15.5°$; **or**
Solution 4: $Im(y_S) = (0.554) + (1.999) = 2.554$; $\theta_{S2} = 72.5°$; $\theta_{P4} = 68.6°$; $\theta_{S4} = 60.5°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 33

1. z = 1.130 + j·1.285; Y = 1 / 50Ω / (1.130 + j·1.285) = 0.0077S + j·(-0.0088)S ; Γ = (z-1)/(z+1) = (1.130 + j·1.285-1)/(1.130 + j·1.285+1) = 0.312+j·(0.415) = 0.519∠53.1°, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20}$ = 0.115, Z_{0E} = 56.112Ω, Z_{0O} = 44.554Ω
b) Pc = 143.0µW = -8.447dBm ; Pin = Pc + C = -8.447dBm + 18.8dB = 10.353dBm = 10.848 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 10.848mW – 0.1430mW – 0 = 10.705 **mW** = 10.296 **dBm**



3. The series RL load with R = 58Ω and L = 1.606nH has Z_L = 58.00Ω + j·(71.64)Ω at 7.1GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j \cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j \cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j \cdot \tan(\beta l)}{1 + j \cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j \cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) tan(βl)=tan(2·π·3/6)=0.000 ; cot(βl)= ∞ ; Z_{in} = 92.18Ω∠51.0° = 58.00Ω + j·(71.64)Ω ;

b) If the line becomes open-circuited Z_L = ∞ ; Z_{in} = j·(0.00)Ω

4. a) G = $G_1 + G_2 + G_3$ = 19dB + 14dB + 12dB = 45dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.05dB=1.603, G_1 = 19dB=79.433, F_2 = 2.34dB=1.714, G_2 = 14dB=25.119, F_3 = 2.10dB=1.622,
F = 1.603 + (1.714−1)/79.433 + (1.622−1)/79.433/25.119 = 1.613 = 2.075dB

5. a) Must compute either µ or µ' (**as requested!**) (L8/2023, S96 or 97);

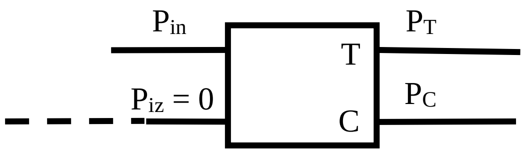
	Δ	|Δ|	K	µ'
T1	-0.452+ j·(0.145)	0.475	0.779	0.828
T2	-0.230+ j·(-0.128)	0.263	0.908	0.957

b) µ' (T1) < µ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2)$ = 0.074 (L9/2023, S101)
d) For T2: MSG = $|S_{21}| / |S_{12}|$ = 23.636 = 13.736 dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}|$ = 0.135, $\arg(S_{22}^*)$ = 150.2° ; θ_{S1} = 153.8° ; $Im(y_S)$ = -0.272 ; **or** θ_{S2} = 56.0° ; $Im(y_S)$ = 0.272
S_{11}^* for T2: 2 solutions for the match, $|S_{11}|$ = 0.628, $\arg(S_{11}^*)$ = 133.6° ; θ_{S3} = 177.7° ; $Im(y_S)$ = -1.614 ; **or** θ_{S4} = 48.7° ; $Im(y_S)$ = 1.614
Combining the two schematics(L13/2023, S96), all lines with Z_0 = 50Ω:
Solution 1: $Im(y_S)$ = (-0.272) + (-1.614) = -1.886; θ_{S1} = 153.8° ; θ_{P1} = 117.9° ; θ_{S3} = 177.7° ; **or**
Solution 2: $Im(y_S)$ = (-0.272) + (1.614) = 1.341; θ_{S1} = 153.8° ; θ_{P2} = 53.3° ; θ_{S4} = 48.7° ; **or**
Solution 3: $Im(y_S)$ = (0.272) + (-1.614) = -1.341; θ_{S2} = 56.0° ; θ_{P3} = 126.7° ; θ_{S3} = 177.7° ; **or**
Solution 4: $Im(y_S)$ = (0.272) + (1.614) = 1.886; θ_{S2} = 56.0° ; θ_{P4} = 62.1° ; θ_{S4} = 48.7° ;
f) Schematic drawing, “T” shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 34

1. z = 1.015 − j·1.245; Y = 1 / 50Ω / (1.015 − j·1.245) = 0.0079S + j·(0.0097)S ; Γ = (z-1)/(z+1) = (1.015 − j·1.245-1)/(1.015 − j·1.245+1) = 0.282+j·(-0.444) = 0.526∠-57.6°, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20}$ = 0.075, Z_{0E} = 53.901Ω, Z_{0O} = 46.381Ω
b) Pc = 93.0μW = -10.315dBm ; Pin = Pc + C = -10.315dBm + 22.5dB = 12.185dBm = 16.538 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 16.538mW – 0.0930mW – 0 = 16.445 **mW** = 12.160 **dBm**



3. The shunt RC load with R = 66Ω and C = 0.383pF has Z_L = 19.56Ω + j·(-30.14)Ω at 9.7GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) tan(βl)=tan(2·π·1/3)=-1.732 ; cot(βl)= -0.577 ; Z_{in} = 331.64Ω∠-42.1° = 246.01Ω + j·(-222.42)Ω ;

b) If the line becomes short-circuited Z_L = 0 ; Z_{in} = j·(-155.88)Ω

4. a) G = $G_1 + G_2 + G_3$ = 19dB + 16dB + 16dB = 51dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.63dB=1.832, G_1 = 19dB=79.433, F_2 = 2.34dB=1.714, G_2 = 16dB=39.811, F_3 = 2.51dB=1.782,
F = 1.832 + (1.714−1)/79.433 + (1.782−1)/79.433/39.811 = 1.842 = 2.652dB

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

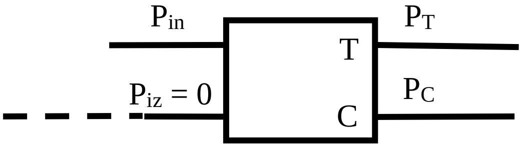
	Δ	|Δ|	K	μ
T1	-0.468+ j·(-0.131)	0.486	0.645	0.519
T2	-0.218+ j·(-0.260)	0.339	0.783	0.827

b) μ (T1) < μ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2)$ = 0.193 (L9/2023, S101)
d) For T2: MSG = $|S_{21}| / |S_{12}|$ = 27.412 = 14.379 dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}|$ = 0.241, arg(S_{22}^*) = 116.7° ; θ_{S1} = 173.6° ; Im(y_S) = -0.497 ; **or** θ_{S2} = 69.7° ; Im(y_S) = 0.497
S_{11}^* for T2: 2 solutions for the match, $|S_{11}|$ = 0.688, arg(S_{11}^*) = 110.0° ; θ_{S3} = 11.7° ; Im(y_S) = -1.896 ; **or** θ_{S4} = 58.3° ; Im(y_S) = 1.896
Combining the two schematics(L13/2023, S96), all lines with Z_0 = 50Ω:
Solution 1: Im(y_S) = (-0.497) + (-1.896) = -2.393; θ_{S1} = 173.6° ; θ_{P1} = 112.7° ; θ_{S3} = 11.7° ; **or**
Solution 2: Im(y_S) = (-0.497) + (1.896) = 1.399; θ_{S1} = 173.6° ; θ_{P2} = 54.5° ; θ_{S4} = 58.3° ; **or**
Solution 3: Im(y_S) = (0.497) + (-1.896) = -1.399; θ_{S2} = 69.7° ; θ_{P3} = 125.5° ; θ_{S3} = 11.7° ; **or**
Solution 4: Im(y_S) = (0.497) + (1.896) = 2.393; θ_{S2} = 69.7° ; θ_{P4} = 67.3° ; θ_{S4} = 58.3° ;
f) Schematic drawing, “T” shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 35

1. z = 0.720 − j·0.880; Y = 1 / 50Ω / (0.720 − j·0.880) = 0.0111S + j·(0.0136)S ; Γ = (z-1)/(z+1) = (0.720 − j·0.880-1)/(0.720 − j·0.880+1) = 0.078+j·(-0.471) = 0.478∠-80.6°, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20}$ = 0.079, Z_{0E} = 54.143Ω, Z_{0O} = 46.174Ω
b) Pc = 67.5μW = -11.707dBm ; Pin = Pc + C = -11.707dBm + 22.0dB = 10.293dBm = 10.698 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 10.698mW – 0.0675mW – 0 = 10.631 **mW** = 10.266 **dBm**



3. The shunt RL load with R = 71Ω and L = 1.063nH has Z_L = 32.62Ω + j·(35.38)Ω at 9.8GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot \tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) tan(βl)=tan(2·π·4/6)=1.732 ; cot(βl)= 0.577 ; Z_{in} = 292.50Ω∠21.6° = 272.03Ω + j·(107.48)Ω ;

b) If the line becomes open-circuited Z_L = ∞ ; Z_{in} = j·(-54.85)Ω

4. a) G = $G_1 + G_2 + G_3$ = 19dB + 11dB + 16dB = 46dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.15dB=1.641, G_1 = 19dB=79.433, F_2 = 2.91dB=1.954, G_2 = 11dB=12.589, F_3 = 2.18dB=1.652,
F = 1.641 + (1.954−1)/79.433 + (1.652−1)/79.433/12.589 = 1.653 = 2.183dB

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

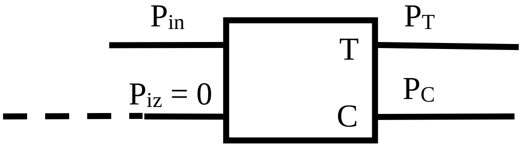
	Δ	|Δ|	K	μ'
T1	-0.480+ j·(-0.009)	0.480	0.707	0.788
T2	-0.231+ j·(-0.204)	0.308	0.834	0.922

b) μ' (T1) < μ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2)$ = 0.130 (L9/2023, S101)
d) For T2: MSG = $|S_{21}| / |S_{12}|$ = 25.336 = 14.037 dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}|$ = 0.195, $\arg(S_{22}^*)$ = 128.8° ; θ_{S1} = 166.2° ; $\mathrm{Im}(y_S)$ = -0.398 ; **or** θ_{S2} = 65.0° ; $\mathrm{Im}(y_S)$ = 0.398
S_{11}^* for T2: 2 solutions for the match, $|S_{11}|$ = 0.658, $\arg(S_{11}^*)$ = 120.0° ; θ_{S3} = 5.6° ; $\mathrm{Im}(y_S)$ = -1.748 ; **or** θ_{S4} = 54.4° ; $\mathrm{Im}(y_S)$ = 1.748
Combining the two schematics(L13/2023, S96), all lines with Z_0 = 50Ω:
Solution 1: $\mathrm{Im}(y_S)$ = (-0.398) + (-1.748) = -2.145; θ_{S1} = 166.2° ; θ_{P1} = 115.0° ; θ_{S3} = 5.6° ; **or**
Solution 2: $\mathrm{Im}(y_S)$ = (-0.398) + (1.748) = 1.350; θ_{S1} = 166.2° ; θ_{P2} = 53.5° ; θ_{S4} = 54.4° ; **or**
Solution 3: $\mathrm{Im}(y_S)$ = (0.398) + (-1.748) = -1.350; θ_{S2} = 65.0° ; θ_{P3} = 126.5° ; θ_{S3} = 5.6° ; **or**
Solution 4: $\mathrm{Im}(y_S)$ = (0.398) + (1.748) = 2.145; θ_{S2} = 65.0° ; θ_{P4} = 65.0° ; θ_{S4} = 54.4° ;
f) Schematic drawing, “T” shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 36

1. $z = 0.990 + j\cdot0.985$; $Y = 1 / 50\Omega / (0.990 + j\cdot0.985) = 0.0102S + j\cdot(-0.0101)S$; $\Gamma = (z-1)/(z+1) = (0.990 + j\cdot0.985-1)/(0.990 + j\cdot0.985+1) = 0.193+j\cdot(0.400) = 0.444\angle64.2°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.075$, $Z_{0E} = 53.901\Omega$, $Z_{0O} = 46.381\Omega$
b) Pc = 78.5µW = -11.051dBm ; Pin = Pc + C = -11.051dBm + 22.5dB = 11.449dBm = 13.959 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 13.959mW – 0.0785mW – 0 = 13.881 **mW** = 11.424 **dBm**



3. The shunt RC load with R = 36Ω and C = 0.331pF has $Z_L = 26.84\Omega + j\cdot(-15.68)\Omega$ at 7.8GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot \tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot4/6)=1.732$; $\cot(\beta l)= 0.577$; $Z_{in} = 56.03\Omega\angle45.0° = 39.62\Omega + j\cdot(39.62)\Omega$;

b) If the line becomes short-circuited $Z_L = 0$; $Z_{in} = j\cdot(103.92)\Omega$

4. a) $G = G_1 + G_2 + G_3$ = 11dB + 12dB + 18dB = 41dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.21dB=1.663, G_1 = 11dB=12.589, F_2 = 2.62dB=1.828, G_2 = 12dB=15.849, F_3 = 2.02dB=1.592,
F = 1.663 + (1.828−1)/12.589 + (1.592−1)/12.589/15.849 = 1.732 = 2.386dB

5. a) Must compute either µ or µ' (**as requested!**) (L8/2023, S96 or 97);

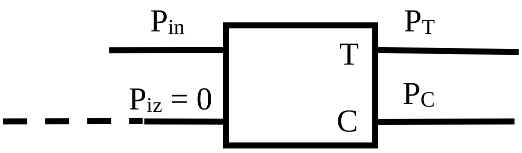
	Δ	|Δ|	K	µ
T1	-0.436+ j·(-0.224)	0.490	0.607	0.482
T2	-0.197+ j·(-0.309)	0.367	0.737	0.789

b) µ (T1) < µ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2) /(1-|S_{22}|^2)$ = 0.248 (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}|$ = 29.163 = 14.648 dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.274$, $\arg(S_{22}^*) = 107.4°$; $\theta_{S1} = 179.3°$; $Im(y_S) = -0.570$; **or** $\theta_{S2} = 73.4°$; $Im(y_S) = 0.570$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.714$, $\arg(S_{11}^*) = 102.0°$; $\theta_{S3} = 16.8°$; $Im(y_S) = -2.040$; **or** $\theta_{S4} = 61.2°$; $Im(y_S) = 2.040$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S)$ = (-0.570) + (-2.040) = -2.609; $\theta_{S1} = 179.3°$; $\theta_{P1} = 111.0°$; $\theta_{S3} = 16.8°$; **or**
Solution 2: $Im(y_S)$ = (-0.570) + (2.040) = 1.470; $\theta_{S1} = 179.3°$; $\theta_{P2} = 55.8°$; $\theta_{S4} = 61.2°$; **or**
Solution 3: $Im(y_S)$ = (0.570) + (-2.040) = -1.470; $\theta_{S2} = 73.4°$; $\theta_{P3} = 124.2°$; $\theta_{S3} = 16.8°$; **or**
Solution 4: $Im(y_S)$ = (0.570) + (2.040) = 2.609; $\theta_{S2} = 73.4°$; $\theta_{P4} = 69.0°$; $\theta_{S4} = 61.2°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 37

1. $z = 0.755 + j\cdot 0.705$; $Y = 1 / 50\Omega / (0.755 + j\cdot 0.705) = 0.0142S + j\cdot(-0.0132)S$; $\Gamma = (z-1)/(z+1) = (0.755 + j\cdot 0.705-1)/(0.755 + j\cdot 0.705+1) = 0.019+j\cdot(0.394) = 0.395\angle 87.3°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.110$, $Z_{0E} = 55.819\Omega$, $Z_{0O} = 44.788\Omega$
b) $P_c = 64.5\mu W = -11.904dBm$; $P_{in} = P_c + C = -11.904dBm + 19.2dB = 7.296dBm = 5.365$ **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 5.365mW – 0.0645mW – 0 = 5.300 **mW** = 7.243 **dBm**



3. The series RC load with R = 29Ω and C = 0.426pF has $Z_L = 29.00\Omega + j\cdot(-47.29)\Omega$ at 7.9GHz

$$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0\cdot\tan(\beta l)}{Z_0 + j\cdot Z_L\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot\cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 4/6)=1.732$; $\cot(\beta l)= 0.577$; $Z_{in} = 8.78\Omega\angle 1.4° = 8.78\Omega + j\cdot(0.22)\Omega$;

b) If the line becomes short-circuited $Z_L = 0$; $Z_{in} = j\cdot(60.62)\Omega$

4. a) $G = G_1 + G_2 + G_3 = 16dB + 15dB + 11dB = 42dB$
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
$F_1 = 2.39dB=1.734$, $G_1 = 16dB=39.811$, $F_2 = 2.09dB=1.618$, $G_2 = 15dB=31.623$, $F_3 = 2.60dB=1.820$,
$F = 1.734 + (1.618-1)/39.811 + (1.820-1)/39.811/31.623 = 1.750 = 2.430dB$

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

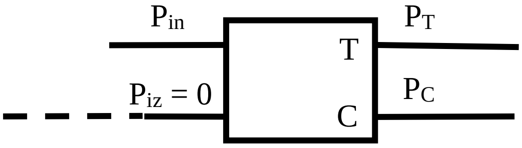
	Δ	|Δ|	K	μ'
T1	-0.479+ j·(-0.034)	0.480	0.694	0.781
T2	-0.229+ j·(-0.214)	0.314	0.824	0.917

b) μ' (T1) < μ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2) = 0.141$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 25.736 = 14.105$ dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.204$, $\arg(S_{22}^*) = 126.4°$; $\theta_{S1} = 167.7°$; $Im(y_S) = -0.417$; **or** $\theta_{S2} = 65.9°$; $Im(y_S) = 0.417$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.664$, $\arg(S_{11}^*) = 118.0°$; $\theta_{S3} = 6.8°$; $Im(y_S) = -1.776$; **or** $\theta_{S4} = 55.2°$; $Im(y_S) = 1.776$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.417) + (-1.776) = -2.193$; $\theta_{S1} = 167.7°$; $\theta_{P1} = 114.5°$; $\theta_{S3} = 6.8°$; **or**
Solution 2: $Im(y_S) = (-0.417) + (1.776) = 1.359$; $\theta_{S1} = 167.7°$; $\theta_{P2} = 53.7°$; $\theta_{S4} = 55.2°$; **or**
Solution 3: $Im(y_S) = (0.417) + (-1.776) = -1.359$; $\theta_{S2} = 65.9°$; $\theta_{P3} = 126.3°$; $\theta_{S3} = 6.8°$; **or**
Solution 4: $Im(y_S) = (0.417) + (1.776) = 2.193$; $\theta_{S2} = 65.9°$; $\theta_{P4} = 65.5°$; $\theta_{S4} = 55.2°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 38

1. z = 1.250 − j·1.275; Y = 1 / 50Ω / (1.250 − j·1.275) = 0.0078S + j·(0.0080)S ; Γ = (z-1)/(z+1) = (1.250 − j·1.275-1)/(1.250 − j·1.275+1) = 0.327+j·(-0.381) = 0.502∠-49.4°, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20}$ = 0.101, Z_{0E} = 55.342Ω, Z_{0O} = 45.174Ω
b) Pc = 85.5µW = -10.680dBm ; Pin = Pc + C = -10.680dBm + 19.9dB = 9.220dBm = 8.355 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 8.355mW – 0.0855mW – 0 = 8.270 **mW** = 9.175 **dBm**



3. The shunt RL load with R = 55Ω and L = 1.165nH has Z_L = 27.08Ω + j·(27.50)Ω at 7.4GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot \tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) tan(βl)=tan(2·π·1/6)=1.732 ; cot(βl)= 0.577 ; Z_{in} = 84.59Ω∠-24.9° = 76.75Ω + j·(-35.57)Ω ;

b) If the line becomes short-circuited Z_L = 0 ; Z_{in} = j·(69.28)Ω

4. a) G = $G_1 + G_2 + G_3$ = 13dB + 15dB + 15dB = 43dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.18dB=1.652, G_1 = 13dB=19.953, F_2 = 2.70dB=1.862, G_2 = 15dB=31.623, F_3 = 2.24dB=1.675,
F = 1.652 + (1.862−1)/19.953 + (1.675−1)/19.953/31.623 = 1.696 = 2.295dB

5. a) Must compute either µ or µ' (**as requested!**) (L8/2023, S96 or 97);

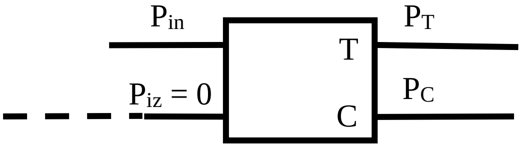
	Δ	|Δ|	K	µ'
T1	-0.110+ j·(0.469)	0.482	0.923	0.933
T2	-0.134+ j·(0.002)	0.134	1.168	1.073

b) µ' (T1) < µ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2)$ = 0.055 (L9/2023, S101)
d) For T2: MSG = $|S_{21}| / |S_{12}|$ = 20.818 = 13.184 dB (L9/2023, S75) ; However K = 1.168 > 1 so maximum gain is MAG = $|S_{21}| / |S_{12}| \cdot [K - \sqrt{(K^2 - 1)}]$ = 11.761 = 10.705 dB (L9/2023, S76)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}|$ = 0.138, arg(S_{22}^*) = -71.9° ; θ_{S1} = 84.9° ; Im(y_S) = -0.279 ; **or** θ_{S2} = 167.0° ; Im(y_S) = 0.279
S_{11}^* for T2: 2 solutions for the match, $|S_{11}|$ = 0.575, arg(S_{11}^*) = 175.0° ; θ_{S3} = 155.0° ; Im(y_S) = -1.406 ; **or** θ_{S4} = 30.0° ; Im(y_S) = 1.406
Combining the two schematics(L13/2023, S96), all lines with Z_0 = 50Ω:
Solution 1: Im(y_S) = (-0.279) + (-1.406) = -1.684; θ_{S1} = 84.9° ; θ_{P1} = 120.7° ; θ_{S3} = 155.0° ; **or**
Solution 2: Im(y_S) = (-0.279) + (1.406) = 1.127; θ_{S1} = 84.9° ; θ_{P2} = 48.4° ; θ_{S4} = 30.0° ; **or**
Solution 3: Im(y_S) = (0.279) + (-1.406) = -1.127; θ_{S2} = 167.0° ; θ_{P3} = 131.6° ; θ_{S3} = 155.0° ; **or**
Solution 4: Im(y_S) = (0.279) + (1.406) = 1.684; θ_{S2} = 167.0° ; θ_{P4} = 59.3° ; θ_{S4} = 30.0° ;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 39

1. $z = 1.205 + j\cdot 1.255$; $Y = 1 / 50\Omega / (1.205 + j\cdot 1.255) = 0.0080S + j\cdot(-0.0083)S$; $\Gamma = (z-1)/(z+1) = (1.205 + j\cdot 1.255-1)/(1.205 + j\cdot 1.255+1) = 0.315+j\cdot(0.390) = 0.501\angle 51.1°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.117$, $Z_{0E} = 56.264\Omega$, $Z_{0O} = 44.433\Omega$
b) $P_c = 137.0\mu W = -8.633dBm$; $P_{in} = P_c + C = -8.633dBm + 18.6dB = 9.967dBm = 9.925$ **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = $P_{in} - P_c - P_{iz} = 9.925mW - 0.1370mW - 0 = 9.788$ **mW** = 9.907 **dBm**



3. The shunt RC load with $R = 64\Omega$ and $C = 0.253pF$ has $Z_L = 33.09\Omega + j\cdot(-31.98)\Omega$ at 9.5GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot \tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 4/5)=-3.078$; $\cot(\beta l)= -0.325$; $Z_{in} = 54.03\Omega\angle 41.9° = 40.22\Omega + j\cdot(36.07)\Omega$;

b) If the line becomes short-circuited $Z_L = 0$; $Z_{in} = j\cdot(-123.11)\Omega$

4. a) $G = G_1 + G_2 + G_3 = 14dB + 12dB + 15dB = 41dB$
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
$F_1 = 2.76dB=1.888$, $G_1 = 14dB=25.119$, $F_2 = 2.86dB=1.932$, $G_2 = 12dB=15.849$, $F_3 = 2.67dB=1.849$,
$F = 1.888 + (1.932-1)/25.119 + (1.849-1)/25.119/15.849 = 1.927 = 2.849dB$

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

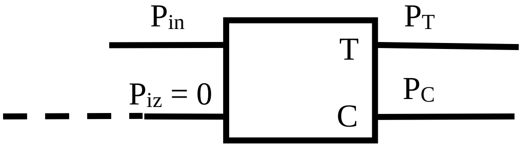
	Δ	$\lvert\Delta\rvert$	K	μ'
T1	$-0.478+ j\cdot(-0.058)$	0.481	0.682	0.775
T2	$-0.227+ j\cdot(-0.225)$	0.320	0.813	0.913

b) μ' (T1) < μ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2) = 0.153$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 26.143 = 14.174$ dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.214$, $\arg(S_{22}^*) = 123.9°$; $\theta_{S1} = 169.2°$; $Im(y_S) = -0.438$; **or** $\theta_{S2} = 66.8°$; $Im(y_S) = 0.438$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.670$, $\arg(S_{11}^*) = 116.0°$; $\theta_{S3} = 8.0°$; $Im(y_S) = -1.805$; **or** $\theta_{S4} = 56.0°$; $Im(y_S) = 1.805$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.438) + (-1.805) = -2.243$; $\theta_{S1} = 169.2°$; $\theta_{P1} = 114.0°$; $\theta_{S3} = 8.0°$; **or**
Solution 2: $Im(y_S) = (-0.438) + (1.805) = 1.367$; $\theta_{S1} = 169.2°$; $\theta_{P2} = 53.8°$; $\theta_{S4} = 56.0°$; **or**
Solution 3: $Im(y_S) = (0.438) + (-1.805) = -1.367$; $\theta_{S2} = 66.8°$; $\theta_{P3} = 126.2°$; $\theta_{S3} = 8.0°$; **or**
Solution 4: $Im(y_S) = (0.438) + (1.805) = 2.243$; $\theta_{S2} = 66.8°$; $\theta_{P4} = 66.0°$; $\theta_{S4} = 56.0°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 40

1. $z = 0.765 - j\cdot 0.985$; $Y = 1 / 50\Omega / (0.765 - j\cdot 0.985) = 0.0098S + j\cdot(0.0127)S$; $\Gamma = (z-1)/(z+1) = (0.765 - j\cdot 0.985-1)/(0.765 - j\cdot 0.985+1) = 0.136+j\cdot(-0.482) = 0.501\angle -74.3°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.085$, $Z_{0E} = 54.453\Omega$, $Z_{0O} = 45.911\Omega$
b) $P_c = 73.0\mu W = -11.367dBm$; $P_{in} = P_c + C = -11.367dBm + 21.4dB = 10.033dBm = 10.077$ **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 10.077mW – 0.0730mW – 0 = 10.004 **mW** = 10.002 **dBm**



3. The shunt RC load with R = 46Ω and C = 0.738pF has $Z_L = 10.73\Omega + j\cdot(-19.45)\Omega$ at 8.5GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0\cdot\tan(\beta l)}{Z_0 + j\cdot Z_L\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot\cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 2/3)=1.732$; $\cot(\beta l)= 0.577$; $Z_{in} = 39.66\Omega\angle 68.4° = 14.60\Omega + j\cdot(36.87)\Omega$;

b) If the line becomes open-circuited $Z_L = \infty$; $Z_{in} = j\cdot(-28.87)\Omega$

4. a) $G = G_1 + G_2 + G_3 = 17dB + 16dB + 17dB = 50dB$
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
$F_1 = 2.38dB=1.730$, $G_1 = 17dB=50.119$, $F_2 = 2.54dB=1.795$, $G_2 = 16dB=39.811$, $F_3 = 2.75dB=1.884$,
$F = 1.730 + (1.795-1)/50.119 + (1.884-1)/50.119/39.811 = 1.746 = 2.421dB$

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

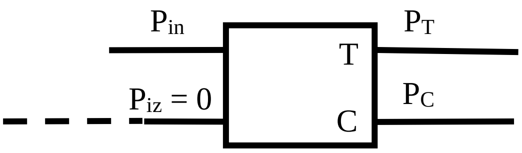
	Δ	|Δ|	K	μ
T1	-0.350+ j·(0.314)	0.470	0.849	0.763
T2	-0.199+ j·(-0.049)	0.205	1.018	1.013

b) μ (T1) < μ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2) = 0.039$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 22.436 = 13.510$ dB (L9/2023, S75) ; However K = 1.018 > 1 so maximum gain is $MAG = |S_{21}| / |S_{12}| \cdot [K - \sqrt{(K^2 - 1)}] = 18.586 = 12.692$ dB (L9/2023, S76)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.087$, $\arg(S_{22}^*) = -160.0°$; $\theta_{S1} = 127.5°$; $Im(y_S) = -0.175$; **or** $\theta_{S2} = 32.5°$; $Im(y_S) = 0.175$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.601$, $\arg(S_{11}^*) = 151.0°$; $\theta_{S3} = 168.0°$; $Im(y_S) = -1.504$; **or** $\theta_{S4} = 41.0°$; $Im(y_S) = 1.504$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.175) + (-1.504) = -1.679$; $\theta_{S1} = 127.5°$; $\theta_{P1} = 120.8°$; $\theta_{S3} = 168.0°$; **or**
Solution 2: $Im(y_S) = (-0.175) + (1.504) = 1.329$; $\theta_{S1} = 127.5°$; $\theta_{P2} = 53.0°$; $\theta_{S4} = 41.0°$; **or**
Solution 3: $Im(y_S) = (0.175) + (-1.504) = -1.329$; $\theta_{S2} = 32.5°$; $\theta_{P3} = 127.0°$; $\theta_{S3} = 168.0°$; **or**
Solution 4: $Im(y_S) = (0.175) + (1.504) = 1.679$; $\theta_{S2} = 32.5°$; $\theta_{P4} = 59.2°$; $\theta_{S4} = 41.0°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 41

1. $z = 1.120 + j\cdot 1.275$; $Y = 1 / 50\Omega / (1.120 + j\cdot 1.275) = 0.0078S + j\cdot(-0.0089)S$; $\Gamma = (z-1)/(z+1) = (1.120 + j\cdot 1.275-1)/(1.120 + j\cdot 1.275+1) = 0.307+j\cdot(0.417) = 0.518\angle 53.6°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.094$, $Z_{0E} = 54.966\Omega$, $Z_{0O} = 45.483\Omega$
b) Pc = 140.5μW = -8.523dBm ; Pin = Pc + C = -8.523dBm + 20.5dB = 11.977dBm = 15.764 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 15.764mW – 0.1405mW – 0 = 15.624 **mW** = 11.938 **dBm**



3. The series RC load with R = 63Ω and C = 0.279pF has $Z_L = 63.00\Omega + j\cdot(-73.13)\Omega$ at 7.8GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0\cdot\tan(\beta l)}{Z_0 + j\cdot Z_L\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot\cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 6/8)=\infty$; $\cot(\beta l)= 0.000$; $Z_{in} = 25.90\Omega\angle 49.3° = 16.90\Omega + j\cdot(19.62)\Omega$;

b) If the line becomes open-circuited $Z_L = \infty$; $Z_{in} = j\cdot(0.00)\Omega$

4. a) $G = G_1 + G_2 + G_3$ = 14dB + 13dB + 17dB = 44dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.84dB=1.923, G_1 = 14dB=25.119, F_2 = 2.21dB=1.663, G_2 = 13dB=19.953, F_3 = 2.03dB=1.596,
F = 1.923 + (1.663−1)/25.119 + (1.596−1)/25.119/19.953 = 1.951 = 2.902dB

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

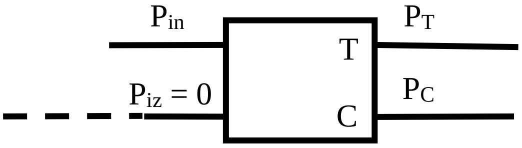
	Δ	|Δ|	K	μ'
T1	-0.410+ j·(0.244)	0.477	0.834	0.863
T2	-0.216+ j·(-0.080)	0.231	0.968	0.985

b) μ' (T1) < μ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2) = 0.045$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}|$ = 22.955 = 13.609 dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.094$, $\arg(S_{22}^*) = 167.8°$; $\theta_{S1} = 143.8°$; $Im(y_S) = -0.189$; **or** $\theta_{S2} = 48.4°$; $Im(y_S) = 0.189$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.613$, $\arg(S_{11}^*) = 143.1°$; $\theta_{S3} = 172.4°$; $Im(y_S) = -1.552$; **or** $\theta_{S4} = 44.5°$; $Im(y_S) = 1.552$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.189) + (-1.552) = -1.741$; $\theta_{S1} = 143.8°$; $\theta_{P1} = 119.9°$; $\theta_{S3} = 172.4°$; **or**
Solution 2: $Im(y_S) = (-0.189) + (1.552) = 1.363$; $\theta_{S1} = 143.8°$; $\theta_{P2} = 53.7°$; $\theta_{S4} = 44.5°$; **or**
Solution 3: $Im(y_S) = (0.189) + (-1.552) = -1.363$; $\theta_{S2} = 48.4°$; $\theta_{P3} = 126.3°$; $\theta_{S3} = 172.4°$; **or**
Solution 4: $Im(y_S) = (0.189) + (1.552) = 1.741$; $\theta_{S2} = 48.4°$; $\theta_{P4} = 60.1°$; $\theta_{S4} = 44.5°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 42

1. $z = 1.225 + j\cdot0.750$; $Y = 1 / 50\Omega / (1.225 + j\cdot0.750) = 0.0119S + j\cdot(-0.0073)S$; $\Gamma = (z-1)/(z+1) = (1.225 + j\cdot0.750-1)/(1.225 + j\cdot0.750+1) = 0.193+j\cdot(0.272) = 0.333\angle54.7°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.122$, $Z_{0E} = 56.500\Omega$, $Z_{0O} = 44.248\Omega$
b) Pc = 148.5µW = -8.283dBm ; Pin = Pc + C = -8.283dBm + 18.3dB = 10.017dBm = 10.040 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 10.040mW – 0.1485mW – 0 = 9.891 **mW** = 9.953 **dBm**



3. The shunt RC load with R = 29Ω and C = 0.566pF has $Z_L = 16.23\Omega + j\cdot(-14.40)\Omega$ at 8.6GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0\cdot\tan(\beta l)}{Z_0 + j\cdot Z_L\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot\cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot4/6)=1.732$; $\cot(\beta l)= 0.577$; $Z_{in} = 116.47\Omega\angle70.6° = 38.61\Omega + j\cdot(109.88)\Omega$;

b) If the line becomes short-circuited $Z_L = 0$; $Z_{in} = j\cdot(164.54)\Omega$

4. a) $G = G_1 + G_2 + G_3$ = 13dB + 13dB + 16dB = 42dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.89dB=1.945, G_1 = 13dB=19.953, F_2 = 2.88dB=1.941, G_2 = 13dB=19.953, F_3 = 2.58dB=1.811,
F = 1.945 + (1.941−1)/19.953 + (1.811−1)/19.953/19.953 = 1.995 = 2.998dB

5. a) Must compute either µ or µ' (**as requested!**) (L8/2023, S96 or 97);

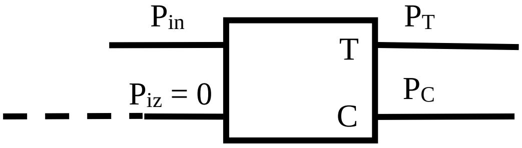
	Δ	|Δ|	K	µ
T1	-0.412+ j·(-0.265)	0.490	0.591	0.467
T2	-0.182+ j·(-0.335)	0.381	0.712	0.768

b) µ (T1) < µ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2) /(1-|S_{22}|^2) = 0.274$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 30.063 = 14.780$ dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.288$, $\arg(S_{22}^*) = 102.9°$; $\theta_{S1} = 1.9°$; $Im(y_S) = -0.601$; **or** $\theta_{S2} = 75.2°$; $Im(y_S) = 0.601$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.728$, $\arg(S_{11}^*) = 98.0°$; $\theta_{S3} = 19.4°$; $Im(y_S) = -2.124$; **or** $\theta_{S4} = 62.6°$; $Im(y_S) = 2.124$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.601) + (-2.124) = -2.725$; $\theta_{S1} = 1.9°$; $\theta_{P1} = 110.2°$; $\theta_{S3} = 19.4°$; **or**
Solution 2: $Im(y_S) = (-0.601) + (2.124) = 1.522$; $\theta_{S1} = 1.9°$; $\theta_{P2} = 56.7°$; $\theta_{S4} = 62.6°$; **or**
Solution 3: $Im(y_S) = (0.601) + (-2.124) = -1.522$; $\theta_{S2} = 75.2°$; $\theta_{P3} = 123.3°$; $\theta_{S3} = 19.4°$; **or**
Solution 4: $Im(y_S) = (0.601) + (2.124) = 2.725$; $\theta_{S2} = 75.2°$; $\theta_{P4} = 69.8°$; $\theta_{S4} = 62.6°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 43

1. $z = 1.275 - j\cdot1.055$; $Y = 1 / 50\Omega / (1.275 - j\cdot1.055) = 0.0093S + j\cdot(0.0077)S$; $\Gamma = (z-1)/(z+1) = (1.275 - j\cdot1.055-1)/(1.275 - j\cdot1.055+1) = 0.276+j\cdot(-0.336) = 0.435\angle{-50.5°}$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.095$, $Z_{0E} = 55.026\Omega$, $Z_{0O} = 45.433\Omega$
b) Pc = 63.0μW = -12.007dBm ; Pin = Pc + C = -12.007dBm + 20.4dB = 8.393dBm = 6.908 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 6.908mW – 0.0630mW – 0 = 6.845 **mW** = 8.354 **dBm**



3. The shunt RC load with R = 53Ω and C = 0.466pF has $Z_L = 18.50\Omega + j\cdot(-25.26)\Omega$ at 8.8GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0\cdot\tan(\beta l)}{Z_0 + j\cdot Z_L\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot\cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot2/6)=-1.732$; $\cot(\beta l)= -0.577$; $Z_{in} = 173.66\Omega\angle{-1.6°} = 173.59\Omega + j\cdot(-4.95)\Omega$;

b) If the line becomes open-circuited $Z_L = \infty$; $Z_{in} = j\cdot(28.87)\Omega$

4. a) $G = G_1 + G_2 + G_3$ = 16dB + 18dB + 10dB = 44dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.25dB=1.679, G_1 = 16dB=39.811, F_2 = 2.45dB=1.758, G_2 = 18dB=63.096, F_3 = 2.48dB=1.770,
F = 1.679 + (1.758−1)/39.811 + (1.770−1)/39.811/63.096 = 1.698 = 2.300dB

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

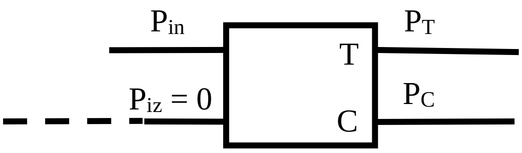
	Δ	|Δ|	K	μ'
T1	-0.062+ j·(0.484)	0.488	0.934	0.942
T2	-0.123+ j·(0.006)	0.123	1.191	1.082

b) μ' (T1) < μ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2) /(1-|S_{22}|^2)$ = 0.063 (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}|$ = 20.527 = 13.123 dB (L9/2023, S75) ; However K = 1.191 > 1 so maximum gain is $MAG = |S_{21}| / |S_{12}| \cdot [K - \sqrt{(K^2 - 1)}]$ = 11.176 = 10.483 dB (L9/2023, S76)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.159$, $\arg(S_{22}^*) = -63.5°$; $\theta_{S1} = 81.3°$; $Im(y_S) = -0.322$; **or** $\theta_{S2} = 162.2°$; $Im(y_S) = 0.322$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.573$, $\arg(S_{11}^*) = 179.0°$; $\theta_{S3} = 153.0°$; $Im(y_S) = -1.398$; **or** $\theta_{S4} = 28.0°$; $Im(y_S) = 1.398$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.322) + (-1.398) = -1.720$; $\theta_{S1} = 81.3°$; $\theta_{P1} = 120.2°$; $\theta_{S3} = 153.0°$; **or**
Solution 2: $Im(y_S) = (-0.322) + (1.398) = 1.076$; $\theta_{S1} = 81.3°$; $\theta_{P2} = 47.1°$; $\theta_{S4} = 28.0°$; **or**
Solution 3: $Im(y_S) = (0.322) + (-1.398) = -1.076$; $\theta_{S2} = 162.2°$; $\theta_{P3} = 132.9°$; $\theta_{S3} = 153.0°$; **or**
Solution 4: $Im(y_S) = (0.322) + (1.398) = 1.720$; $\theta_{S2} = 162.2°$; $\theta_{P4} = 59.8°$; $\theta_{S4} = 28.0°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 44

1. $z = 0.965 + j\cdot1.110$; $Y = 1 / 50\Omega / (0.965 + j\cdot1.110) = 0.0089S + j\cdot(-0.0103)S$; $\Gamma = (z-1)/(z+1) = (0.965 + j\cdot1.110-1)/(0.965 + j\cdot1.110+1) = 0.228+j\cdot(0.436) = 0.492\angle 62.3°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.072$, $Z_{0E} = 53.719\Omega$, $Z_{0O} = 46.539\Omega$
b) Pc = 145.0μW = -8.386dBm ; Pin = Pc + C = -8.386dBm + 22.9dB = 14.514dBm = 28.273 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 28.273mW – 0.1450mW – 0 = 28.128 **mW** = 14.491 **dBm**



3. The series RC load with R = 39Ω and C = 0.336pF has $Z_L = 39.00\Omega + j\cdot(-48.83)\Omega$ at 9.7GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot3/6)=0.000$; $\cot(\beta l)= \infty$; $Z_{in} = 62.49\Omega\angle -51.4° = 39.00\Omega + j\cdot(-48.83)\Omega$;

b) If the line becomes open-circuited $Z_L = \infty$; $Z_{in} = j\cdot(0.00)\Omega$

4. a) $G = G_1 + G_2 + G_3$ = 10dB + 16dB + 14dB = 40dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.95dB=1.972, G_1 = 10dB=10.000, F_2 = 2.43dB=1.750, G_2 = 16dB=39.811, F_3 = 2.34dB=1.714,
F = 1.972 + (1.750−1)/10.000 + (1.714−1)/10.000/39.811 = 2.049 = 3.116dB

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

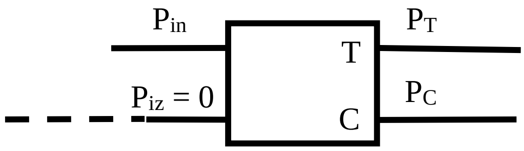
	Δ	|Δ|	K	μ'
T1	-0.087+ j·(0.478)	0.486	0.926	0.935
T2	-0.129+ j·(0.004)	0.129	1.179	1.078

b) μ' (T1) < μ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2) /(1-|S_{22}|^2)$ = 0.060 (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}|$ = 20.673 = 13.154 dB (L9/2023, S75) ; However K = 1.179 > 1 so maximum gain is $MAG = |S_{21}| / |S_{12}| \cdot [K - \sqrt{(K^2 - 1)}]$ = 11.465 = 10.594 dB (L9/2023, S76)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}|$ = 0.149, $\arg(S_{22}^*)$ = -67.7° ; θ_{S1} = 83.1° ; $Im(y_S)$ = -0.301 ; **or** θ_{S2} = 164.6° ; $Im(y_S)$ = 0.301
S_{11}^* for T2: 2 solutions for the match, $|S_{11}|$ = 0.574, $\arg(S_{11}^*)$ = 177.0° ; θ_{S3} = 154.0° ; $Im(y_S)$ = -1.402 ; **or** θ_{S4} = 29.0° ; $Im(y_S)$ = 1.402
Combining the two schematics(L13/2023, S96), all lines with Z_0 = 50Ω:
Solution 1: $Im(y_S)$ = (-0.301) + (-1.402) = -1.703; θ_{S1} = 83.1° ; θ_{P1} = 120.4° ; θ_{S3} = 154.0° ; **or**
Solution 2: $Im(y_S)$ = (-0.301) + (1.402) = 1.101; θ_{S1} = 83.1° ; θ_{P2} = 47.7° ; θ_{S4} = 29.0° ; **or**
Solution 3: $Im(y_S)$ = (0.301) + (-1.402) = -1.101; θ_{S2} = 164.6° ; θ_{P3} = 132.3° ; θ_{S3} = 154.0° ; **or**
Solution 4: $Im(y_S)$ = (0.301) + (1.402) = 1.703; θ_{S2} = 164.6° ; θ_{P4} = 59.6° ; θ_{S4} = 29.0° ;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 45

1. $z = 1.250 - j\cdot 0.835$; $Y = 1 / 50\Omega / (1.250 - j\cdot 0.835) = 0.0111S + j\cdot(0.0074)S$; $\Gamma = (z-1)/(z+1) = (1.250 - j\cdot 0.835-1)/(1.250 - j\cdot 0.835+1) = 0.219+j\cdot(-0.290) = 0.363\angle -53.0°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.129$, $Z_{0E} = 56.916\Omega$, $Z_{0O} = 43.925\Omega$
b) Pc = 70.5µW = -11.518dBm ; Pin = Pc + C = -11.518dBm + 17.8dB = 6.282dBm = 4.248 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 4.248mW – 0.0705mW – 0 = 4.178 **mW** = 6.209 **dBm**



3. The shunt RC load with R = 33Ω and C = 0.557pF has $Z_L = 17.40\Omega + j\cdot(-16.48)\Omega$ at 8.2GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot \tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l) = \tan(2\cdot\pi\cdot 4/8) = 0.000$; $\cot(\beta l) = \infty$; $Z_{in} = 23.96\Omega\angle -43.4° = 17.40\Omega + j\cdot(-16.48)\Omega$;

b) If the line becomes open-circuited $Z_L = \infty$; $Z_{in} = j\cdot(0.00)\Omega$

4. a) $G = G_1 + G_2 + G_3$ = 15dB + 17dB + 17dB = 49dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.01dB=1.589, G_1 = 15dB=31.623, F_2 = 2.48dB=1.770, G_2 = 17dB=50.119, F_3 = 2.81dB=1.910,
F = 1.589 + (1.770−1)/31.623 + (1.910−1)/31.623/50.119 = 1.613 = 2.078dB

5. a) Must compute either µ or µ' (**as requested!**) (L8/2023, S96 or 97);

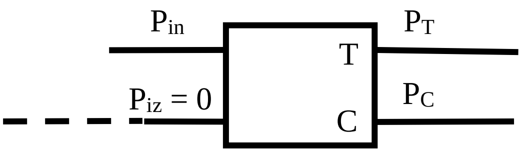
	Δ	|Δ|	K	µ
T1	-0.437+ j·(0.183)	0.474	0.801	0.698
T2	-0.226+ j·(-0.107)	0.250	0.931	0.947

b) µ (T1) < µ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2)$ = 0.061 (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}|$ = 23.364 = 13.685 dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.118$, $\arg(S_{22}^*) = 157.2°$; $\theta_{S1} = 149.8°$; $Im(y_S) = -0.238$; **or** $\theta_{S2} = 53.0°$; $Im(y_S) = 0.238$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.622$, $\arg(S_{11}^*) = 137.4°$; $\theta_{S3} = 175.5°$; $Im(y_S) = -1.589$; **or** $\theta_{S4} = 47.1°$; $Im(y_S) = 1.589$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S)$ = (-0.238) + (-1.589) = -1.826; $\theta_{S1} = 149.8°$; $\theta_{P1} = 118.7°$; $\theta_{S3} = 175.5°$; **or**
Solution 2: $Im(y_S)$ = (-0.238) + (1.589) = 1.351; $\theta_{S1} = 149.8°$; $\theta_{P2} = 53.5°$; $\theta_{S4} = 47.1°$; **or**
Solution 3: $Im(y_S)$ = (0.238) + (-1.589) = -1.351; $\theta_{S2} = 53.0°$; $\theta_{P3} = 126.5°$; $\theta_{S3} = 175.5°$; **or**
Solution 4: $Im(y_S)$ = (0.238) + (1.589) = 1.826; $\theta_{S2} = 53.0°$; $\theta_{P4} = 61.3°$; $\theta_{S4} = 47.1°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 46

1. $z = 1.005 - j\cdot 1.190$; $Y = 1 / 50\Omega / (1.005 - j\cdot 1.190) = 0.0083S + j\cdot(0.0098)S$; $\Gamma = (z-1)/(z+1) = (1.005 - j\cdot 1.190-1)/(1.005 - j\cdot 1.190+1) = 0.262+j\cdot(-0.438) = 0.510\angle -59.1°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.072$, $Z_{0E} = 53.719\Omega$, $Z_{0O} = 46.539\Omega$
b) Pc = 72.0μW = -11.427dBm ; Pin = Pc + C = -11.427dBm + 22.9dB = 11.473dBm = 14.039 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 14.039mW – 0.0720mW – 0 = 13.967 **mW** = 11.451 **dBm**



3. The series RC load with R = 73Ω and C = 0.363pF has $Z_L = 73.00\Omega + j\cdot(-49.26)\Omega$ at 8.9GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot \tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 4/6)=1.732$; $\cot(\beta l)= 0.577$; $Z_{in} = 39.95\Omega\angle 9.6° = 39.40\Omega + j\cdot(6.65)\Omega$;

b) If the line becomes open-circuited $Z_L = \infty$; $Z_{in} = j\cdot(-43.30)\Omega$

4. a) $G = G_1 + G_2 + G_3$ = 12dB + 10dB + 17dB = 39dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.03dB=1.596, G_1 = 12dB=15.849, F_2 = 2.08dB=1.614, G_2 = 10dB=10.000, F_3 = 2.29dB=1.694,
F = 1.596 + (1.614−1)/15.849 + (1.694−1)/15.849/10.000 = 1.639 = 2.146dB

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

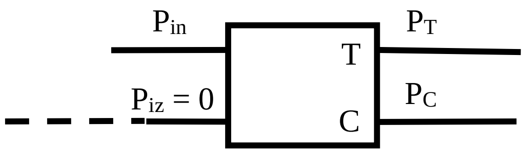
	Δ	|Δ|	K	μ'
T1	-0.457+ j·(0.125)	0.474	0.771	0.824
T2	-0.232+ j·(-0.139)	0.270	0.898	0.951

b) μ' (T1) < μ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2) /(1-|S_{22}|^2)$ = 0.080 (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}|$ = 23.773 = 13.761 dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.143$, $\arg(S_{22}^*) = 146.7°$; $\theta_{S1} = 155.8°$; $Im(y_S) = -0.289$; **or** $\theta_{S2} = 57.6°$; $Im(y_S) = 0.289$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.631$, $\arg(S_{11}^*) = 131.7°$; $\theta_{S3} = 178.7°$; $Im(y_S) = -1.627$; **or** $\theta_{S4} = 49.6°$; $Im(y_S) = 1.627$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.289) + (-1.627) = -1.916$; $\theta_{S1} = 155.8°$; $\theta_{P1} = 117.6°$; $\theta_{S3} = 178.7°$; **or**
Solution 2: $Im(y_S) = (-0.289) + (1.627) = 1.338$; $\theta_{S1} = 155.8°$; $\theta_{P2} = 53.2°$; $\theta_{S4} = 49.6°$; **or**
Solution 3: $Im(y_S) = (0.289) + (-1.627) = -1.338$; $\theta_{S2} = 57.6°$; $\theta_{P3} = 126.8°$; $\theta_{S3} = 178.7°$; **or**
Solution 4: $Im(y_S) = (0.289) + (1.627) = 1.916$; $\theta_{S2} = 57.6°$; $\theta_{P4} = 62.4°$; $\theta_{S4} = 49.6°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 47

1. $z = 1.260 + j\cdot 0.925$; $Y = 1 / 50\Omega / (1.260 + j\cdot 0.925) = 0.0103S + j\cdot(-0.0076)S$; $\Gamma = (z-1)/(z+1) = (1.260 + j\cdot 0.925-1)/(1.260 + j\cdot 0.925+1) = 0.242+j\cdot(0.310) = 0.393\angle 52.0°$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.122$, $Z_{0E} = 56.500\Omega$, $Z_{0O} = 44.248\Omega$
b) $P_c = 110.5\mu W = -9.566dBm$; $P_{in} = P_c + C = -9.566dBm + 18.3dB = 8.734dBm = 7.471$ **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 7.471mW – 0.1105mW – 0 = 7.360 **mW** = 8.669 **dBm**



3. The series RL load with R = 40Ω and L = 1.230nH has $Z_L = 40.00\Omega + j\cdot(62.60)\Omega$ at 8.1GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0\cdot\tan(\beta l)}{Z_0 + j\cdot Z_L\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0\cdot\tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0\cdot\cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 2/5)=-0.727$; $\cot(\beta l)= -1.376$; $Z_{in} = 23.97\Omega\angle 50.2° = 15.34\Omega + j\cdot(18.43)\Omega$;

b) If the line becomes open-circuited $Z_L = \infty$; $Z_{in} = j\cdot(68.82)\Omega$

4. a) $G = G_1 + G_2 + G_3 = 18dB + 12dB + 14dB = 44dB$
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
$F_1 = 2.45dB=1.758$, $G_1 = 18dB=63.096$, $F_2 = 2.42dB=1.746$, $G_2 = 12dB=15.849$, $F_3 = 2.50dB=1.778$,
$F = 1.758 + (1.746-1)/63.096 + (1.778-1)/63.096/15.849 = 1.771 = 2.481dB$

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

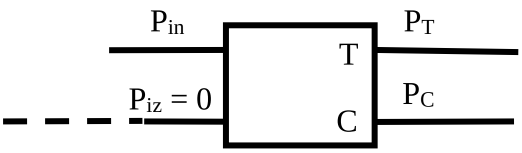
	Δ	|Δ|	K	μ
T1	-0.009+ j·(0.493)	0.493	0.950	0.913
T2	-0.113+ j·(0.007)	0.113	1.215	1.159

b) μ (T1) < μ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2) = 0.071$ (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}| = 20.236 = 13.061$ dB (L9/2023, S75) ; However K = 1.215 > 1 so maximum gain is $MAG = |S_{21}| / |S_{12}| \cdot [K - \sqrt{(K^2 - 1)}] = 10.622 = 10.262$ dB (L9/2023, S76)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.179$, $\arg(S_{22}^*) = -55.1°$; $\theta_{S1} = 77.7°$; $\mathrm{Im}(y_S) = -0.364$; **or** $\theta_{S2} = 157.4°$; $\mathrm{Im}(y_S) = 0.364$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.571$, $\arg(S_{11}^*) = -177.0°$; $\theta_{S3} = 150.9°$; $\mathrm{Im}(y_S) = -1.391$; **or** $\theta_{S4} = 26.1°$; $\mathrm{Im}(y_S) = 1.391$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $\mathrm{Im}(y_S) = (-0.364) + (-1.391) = -1.755$; $\theta_{S1} = 77.7°$; $\theta_{P1} = 119.7°$; $\theta_{S3} = 150.9°$; **or**
Solution 2: $\mathrm{Im}(y_S) = (-0.364) + (1.391) = 1.027$; $\theta_{S1} = 77.7°$; $\theta_{P2} = 45.8°$; $\theta_{S4} = 26.1°$; **or**
Solution 3: $\mathrm{Im}(y_S) = (0.364) + (-1.391) = -1.027$; $\theta_{S2} = 157.4°$; $\theta_{P3} = 134.2°$; $\theta_{S3} = 150.9°$; **or**
Solution 4: $\mathrm{Im}(y_S) = (0.364) + (1.391) = 1.755$; $\theta_{S2} = 157.4°$; $\theta_{P4} = 60.3°$; $\theta_{S4} = 26.1°$;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 48

1. z = 1.165 − j·0.725; Y = 1 / 50Ω / (1.165 − j·0.725) = 0.0124S + j·(0.0077)S ; Γ = (z-1)/(z+1) = (1.165 − j·0.725-1)/(1.165 − j·0.725+1) = 0.169+j·(-0.278) = 0.326∠-58.7°, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20}$ = 0.079, Z_{0E} = 54.143Ω, Z_{0O} = 46.174Ω
b) Pc = 71.0μW = -11.487dBm ; Pin = Pc + C = -11.487dBm + 22.0dB = 10.513dBm = 11.253 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 11.253mW – 0.0710mW – 0 = 11.182 **mW** = 10.485 **dBm**



3. The series RC load with R = 56Ω and C = 0.435pF has Z_L = 56.00Ω + j·(-51.53)Ω at 7.1GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j \cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j \cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j \cdot \tan(\beta l)}{1 + j \cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j \cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) tan(βl)=tan(2·π·2/8)=∞ ; cot(βl)= 0.000 ; Z_{in} = 16.10Ω∠42.6° = 11.84Ω + j·(10.90)Ω ;

b) If the line becomes open-circuited Z_L = ∞ ; Z_{in} = j·(0.00)Ω

4. a) G = $G_1 + G_2 + G_3$ = 12dB + 11dB + 19dB = 42dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.46dB=1.762, G_1 = 12dB=15.849, F_2 = 2.64dB=1.837, G_2 = 11dB=12.589, F_3 = 2.93dB=1.963,
F = 1.762 + (1.837−1)/15.849 + (1.963−1)/15.849/12.589 = 1.820 = 2.600dB

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

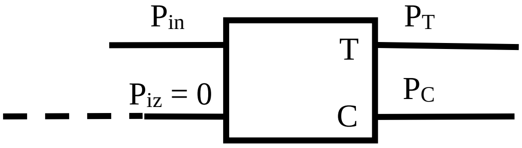
	Δ	|Δ|	K	μ'
T1	-0.472+ j·(-0.107)	0.484	0.658	0.764
T2	-0.221+ j·(-0.248)	0.333	0.793	0.905

b) μ' (T1) < μ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2)$ = 0.178 (L9/2023, S101)
d) For T2: MSG = $|S_{21}| / |S_{12}|$ = 26.981 = 14.311 dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}|$ = 0.232, arg(S_{22}^*) = 119.1° ; θ_{S1} = 172.2° ; Im(y_S) = -0.477 ; **or** θ_{S2} = 68.8° ; Im(y_S) = 0.477
S_{11}^* for T2: 2 solutions for the match, $|S_{11}|$ = 0.682, arg(S_{11}^*) = 112.0° ; θ_{S3} = 10.5° ; Im(y_S) = -1.865 ; **or** θ_{S4} = 57.5° ; Im(y_S) = 1.865
Combining the two schematics(L13/2023, S96), all lines with Z_0 = 50Ω:
Solution 1: Im(y_S) = (-0.477) + (-1.865) = -2.342; θ_{S1} = 172.2° ; θ_{P1} = 113.1° ; θ_{S3} = 10.5° ; **or**
Solution 2: Im(y_S) = (-0.477) + (1.865) = 1.388; θ_{S1} = 172.2° ; θ_{P2} = 54.2° ; θ_{S4} = 57.5° ; **or**
Solution 3: Im(y_S) = (0.477) + (-1.865) = -1.388; θ_{S2} = 68.8° ; θ_{P3} = 125.8° ; θ_{S3} = 10.5° ; **or**
Solution 4: Im(y_S) = (0.477) + (1.865) = 2.342; θ_{S2} = 68.8° ; θ_{P4} = 66.9° ; θ_{S4} = 57.5° ;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 49

1. z = 0.955 – j·0.850; Y = 1 / 50Ω / (0.955 – j·0.850) = 0.0117S + j·(0.0104)S ; Γ = (z-1)/(z+1) = (0.955 – j·0.850-1)/(0.955 – j·0.850+1) = 0.140+j·(-0.374) = 0.399∠-69.5°, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20}$ = 0.129, Z_{0E} = 56.916Ω, Z_{0O} = 43.925Ω
b) Pc = 91.5μW = -10.386dBm ; Pin = Pc + C = -10.386dBm + 17.8dB = 7.414dBm = 5.513 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 5.513mW – 0.0915mW – 0 = 5.422 **mW** = 7.342 **dBm**



3. The series RC load with R = 73Ω and C = 0.337pF has Z_L = 73.00Ω + j·(-54.92)Ω at 8.6GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot \tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) tan(βl)=tan(2·π·3/6)=0.000 ; cot(βl)= ∞ ; Z_{in} = 91.35Ω∠-37.0° = 73.00Ω + j·(-54.92)Ω ;

b) If the line becomes open-circuited Z_L = ∞ ; Z_{in} = j·(0.00)Ω

4. a) G = $G_1 + G_2 + G_3$ = 16dB + 10dB + 11dB = 37dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.75dB=1.884, G_1 = 16dB=39.811, F_2 = 2.61dB=1.824, G_2 = 10dB=10.000, F_3 = 2.74dB=1.879,
F = 1.884 + (1.824–1)/39.811 + (1.879–1)/39.811/10.000 = 1.907 = 2.802dB

5. a) Must compute either μ or μ' (**as requested!**) (L8/2023, S96 or 97);

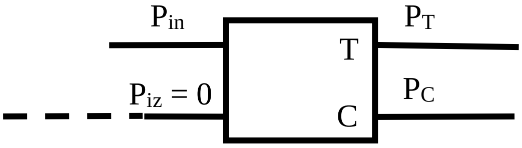
	Δ	|Δ|	K	μ
T1	-0.458+ j·(-0.179)	0.492	0.622	0.494
T2	-0.208+ j·(-0.284)	0.352	0.763	0.810

b) μ (T1) < μ (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2)$ = 0.225 (L9/2023, S101)
d) For T2: MSG = $|S_{21}| / |S_{12}|$ = 28.300 = 14.518 dB (L9/2023, S75)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}|$ = 0.260, arg(S_{22}^*) = 111.8° ; θ_{S1} = 176.6° ; Im(y_S) = -0.539 ; **or** θ_{S2} = 71.6° ; Im(y_S) = 0.539
S_{11}^* for T2: 2 solutions for the match, $|S_{11}|$ = 0.700, arg(S_{11}^*) = 106.0° ; θ_{S3} = 14.2° ; Im(y_S) = -1.960 ; **or** θ_{S4} = 59.8° ; Im(y_S) = 1.960
Combining the two schematics(L13/2023, S96), all lines with Z_0 = 50Ω:
Solution 1: Im(y_S) = (-0.539) + (-1.960) = -2.499; θ_{S1} = 176.6° ; θ_{P1} = 111.8° ; θ_{S3} = 14.2° ; **or**
Solution 2: Im(y_S) = (-0.539) + (1.960) = 1.422; θ_{S1} = 176.6° ; θ_{P2} = 54.9° ; θ_{S4} = 59.8° ; **or**
Solution 3: Im(y_S) = (0.539) + (-1.960) = -1.422; θ_{S2} = 71.6° ; θ_{P3} = 125.1° ; θ_{S3} = 14.2° ; **or**
Solution 4: Im(y_S) = (0.539) + (1.960) = 2.499; θ_{S2} = 71.6° ; θ_{P4} = 68.2° ; θ_{S4} = 59.8° ;
f) Schematic drawing, "T" shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines

Subject no. 50

1. $z = 1.250 - j\cdot 0.750$; $Y = 1 / 50\Omega / (1.250 - j\cdot 0.750) = 0.0118S + j\cdot(0.0071)S$; $\Gamma = (z-1)/(z+1) = (1.250 - j\cdot 0.750-1)/(1.250 - j\cdot 0.750+1) = 0.200+j\cdot(-0.267) = 0.333\angle{-53.1°}$, plot point in complex plane either with rectangular coordinates or polar coordinates

2. a) $\beta = 10^{-C/20} = 0.077$, $Z_{0E} = 53.996\Omega$, $Z_{0O} = 46.300\Omega$
b) Pc = 54.0µW = -12.676dBm ; Pin = Pc + C = -12.676dBm + 22.3dB = 9.624dBm = 9.171 **mW** ;
c) Lossless/Ideal coupler: P_T [mW] = Pin – Pc – Piz = 9.171mW – 0.0540mW – 0 = 9.117 **mW** = 9.598 **dBm**



3. The shunt RL load with R = 35Ω and L = 0.638nH has $Z_L = 14.86\Omega + j\cdot(17.30)\Omega$ at 7.5GHz

$Z_{in} = Z_0 \cdot \frac{Z_L + j\cdot Z_0 \cdot \tan(\beta l)}{Z_0 + j\cdot Z_L \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 + j\cdot\tan(\beta l)}{1 + j\cdot Z_L/Z_0 \cdot \tan(\beta l)} = Z_0 \cdot \frac{Z_L/Z_0 \cdot \cot(\beta l) + j}{\cot(\beta l) + j\cdot Z_L/Z_0}$ (use the appropriate formula if tan or cot are ∞);

a) $\tan(\beta l)=\tan(2\cdot\pi\cdot 5/8)=1.000$; $\cot(\beta l)= 1.000$; $Z_{in} = 95.94\Omega\angle 53.1° = 57.59\Omega + j\cdot(76.73)\Omega$;

b) If the line becomes short-circuited $Z_L = 0$; $Z_{in} = j\cdot(50.00)\Omega$

4. a) $G = G_1 + G_2 + G_3$ = 16dB + 10dB + 11dB = 37dB
b) Friis formula, $F = F_1 + (F_2-1)/G_1 + (F_3-1)/G_1/G_2$
F_1 = 2.27dB=1.687, G_1 = 16dB=39.811, F_2 = 2.99dB=1.991, G_2 = 10dB=10.000, F_3 = 2.52dB=1.786,
F = 1.687 + (1.991−1)/39.811 + (1.786−1)/39.811/10.000 = 1.713 = 2.339dB

5. a) Must compute either µ or µ' (**as requested!**) (L8/2023, S96 or 97);

	Δ	|Δ|	K	µ'
T1	-0.134+ j·(0.463)	0.482	0.917	0.928
T2	-0.140+ j·(0.000)	0.140	1.156	1.069

b) µ' (T1) < µ' (T2) so the transistor T2 has better stability
c) For T1: $U = |S_{11}|\cdot|S_{12}|\cdot|S_{21}|\cdot|S_{22}|/(1-|S_{11}|^2)/(1-|S_{22}|^2)$ = 0.052 (L9/2023, S101)
d) For T2: $MSG = |S_{21}| / |S_{12}|$ = 20.964 = 13.215 dB (L9/2023, S75) ; However K = 1.156 > 1 so maximum gain is $MAG = |S_{21}| / |S_{12}| \cdot [K - \sqrt{(K^2 - 1)}]$ = 12.066 = 10.816 dB (L9/2023, S76)
e) Match is performed from S_{22}^* for T1 to S_{11}^* for T2, Complex calculus from L7/2023, S84÷88
S_{22}^* for T1: 2 solutions for the match, $|S_{22}| = 0.128$, $\arg(S_{22}^*) = -76.1°$; $\theta_{S1} = 86.7°$; $Im(y_S) = -0.258$; **or** $\theta_{S2} = 169.4°$; $Im(y_S) = 0.258$
S_{11}^* for T2: 2 solutions for the match, $|S_{11}| = 0.576$, $\arg(S_{11}^*) = 173.0°$; $\theta_{S3} = 156.1°$; $Im(y_S) = -1.409$; **or** $\theta_{S4} = 30.9°$; $Im(y_S) = 1.409$
Combining the two schematics(L13/2023, S96), all lines with $Z_0 = 50\Omega$:
Solution 1: $Im(y_S) = (-0.258) + (-1.409) = -1.667$; $\theta_{S1} = 86.7°$; $\theta_{P1} = 121.0°$; $\theta_{S3} = 156.1°$; **or**
Solution 2: $Im(y_S) = (-0.258) + (1.409) = 1.151$; $\theta_{S1} = 86.7°$; $\theta_{P2} = 49.0°$; $\theta_{S4} = 30.9°$; **or**
Solution 3: $Im(y_S) = (0.258) + (-1.409) = -1.151$; $\theta_{S2} = 169.4°$; $\theta_{P3} = 131.0°$; $\theta_{S3} = 156.1°$; **or**
Solution 4: $Im(y_S) = (0.258) + (1.409) = 1.667$; $\theta_{S2} = 169.4°$; $\theta_{P4} = 59.0°$; $\theta_{S4} = 30.9°$;
f) Schematic drawing, “T” shaped, the combined shunt stub $\theta_{P1}/\theta_{P2}/\theta_{P3}/\theta_{P4}$ must be between the two series lines