Clicker lecture 1 of Topic 2: Smith chart

Jan 24, 2019

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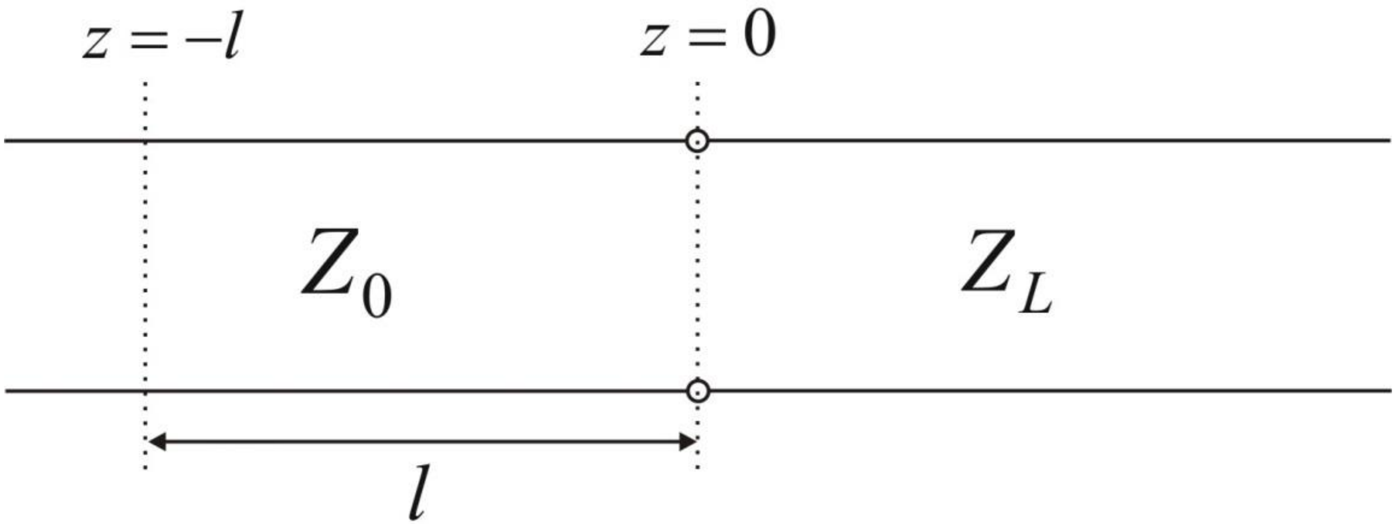
Recapitulation of Topic 1



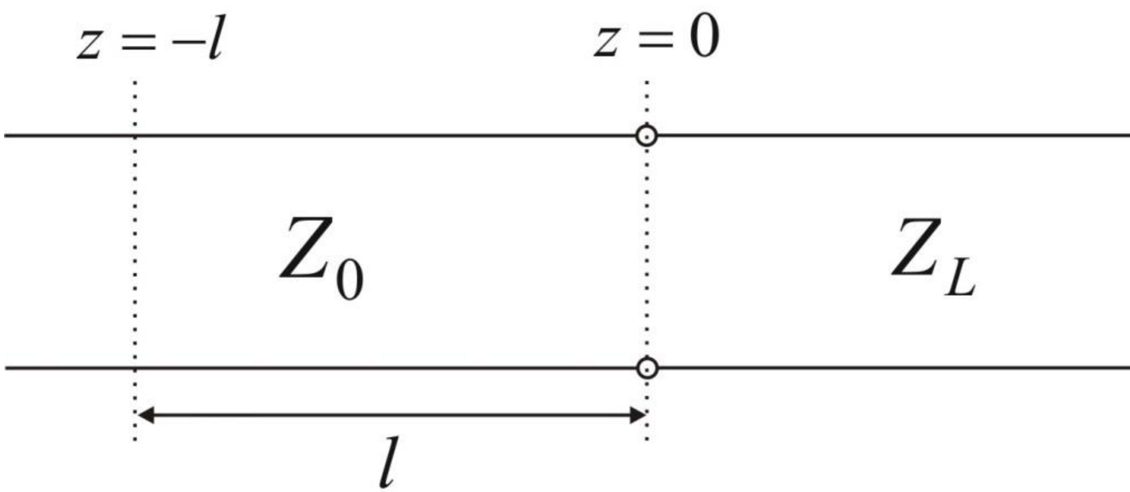
$$\boxed{\rho_L(z=0) = \frac{\text{reflected voltage at } z=0}{\text{forward voltage at } z=0} = \frac{V^-}{V^+} = \frac{Z_L - Z_0}{Z_L + Z_0}}$$

$$\boxed{\tau = 1 + \rho_L}$$

Voltage along the line (z < 0):

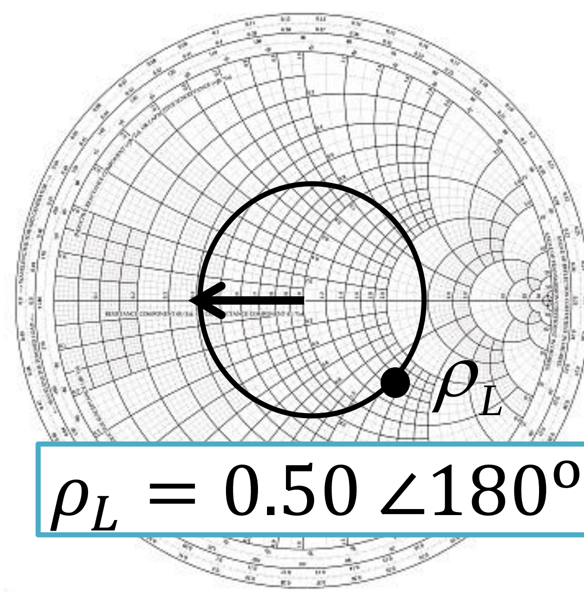
$$\boxed{V(z) = V^+ e^{-j\beta\cdot z} + V^- e^{+j\beta\cdot z} = V^+\, e^{-j\beta\cdot z}\left(1 + \rho_L \cdot e^{+j2\beta z}\right)}$$

Q1a: The signal propagates to the positive z direction. $Z_o \neq Z_L$. How much (%) of the **power** is transmitted to the line whose impedance is Z_L

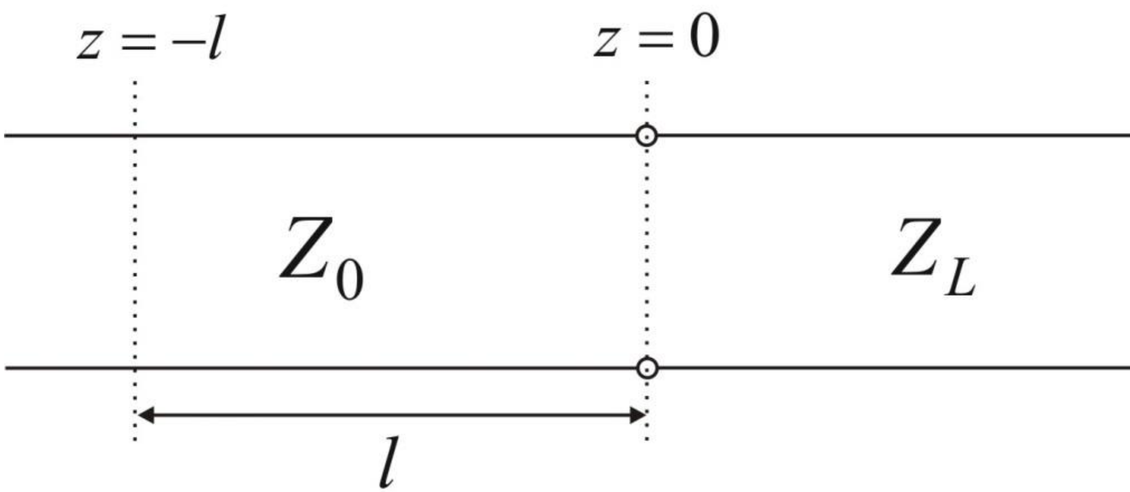


$\rho_L = 0.50 \angle 180^o$

1. 12.5 %
2. 25%
3. 50%
4. 75%
5. 100 %
6. I don’t know



Q1b: The signal propagates to the positive z direction. $Z_o \neq Z_L$. How much (%) of the **power** is transmitted to the line whose impedance is Z_L



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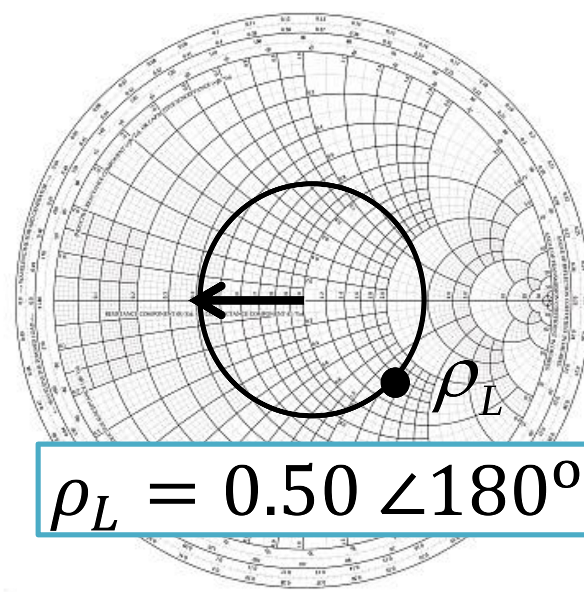
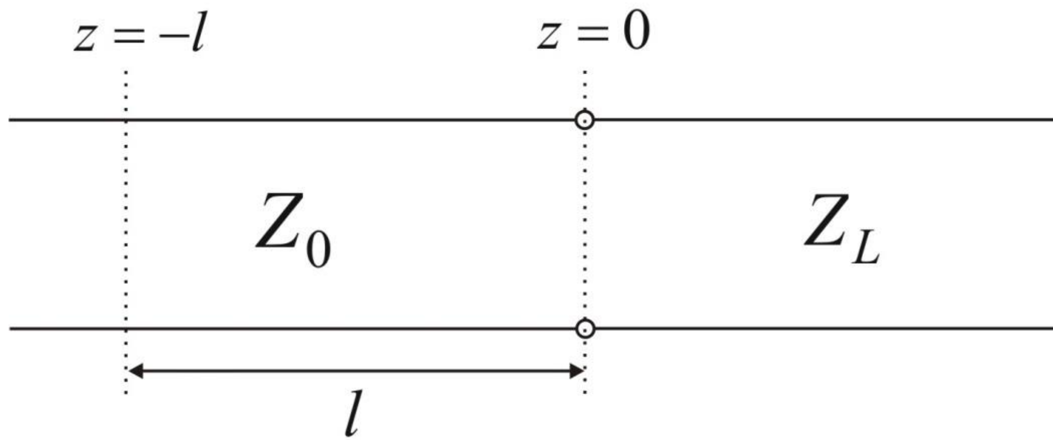


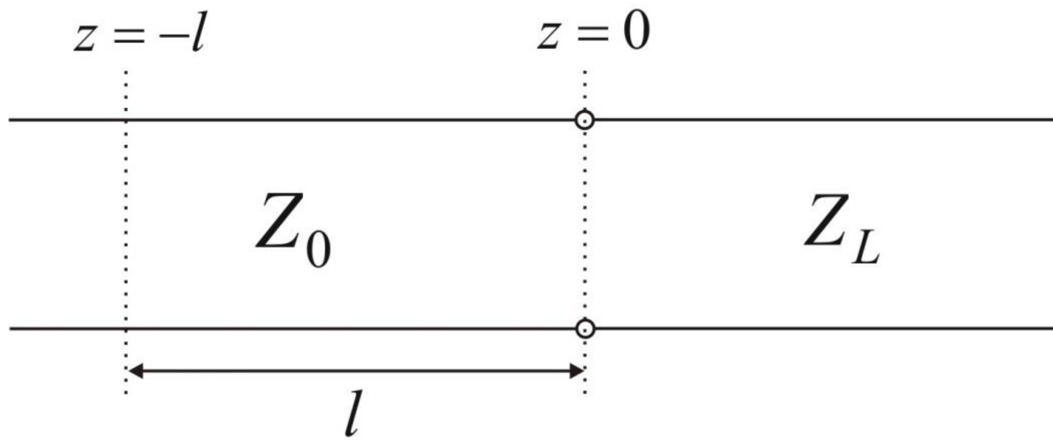
Q2a: ρ_L is the reflection coefficient at z = 0. Which (1-5) is the expression for **ρ at the distance of l from z = 0**?

1. $\rho(z=-l)=\rho_L \cdot e^{-j\beta l}$
2. $\rho(z=-l)=\rho_L \cdot e^{+j\beta l}$
3. $\rho(z=-l)=\rho_L \cdot e^{-j2\beta l}$
4. $\rho(z=-l)=\rho_L \cdot e^{j2\beta l}$
5. None of above
6. I don't know

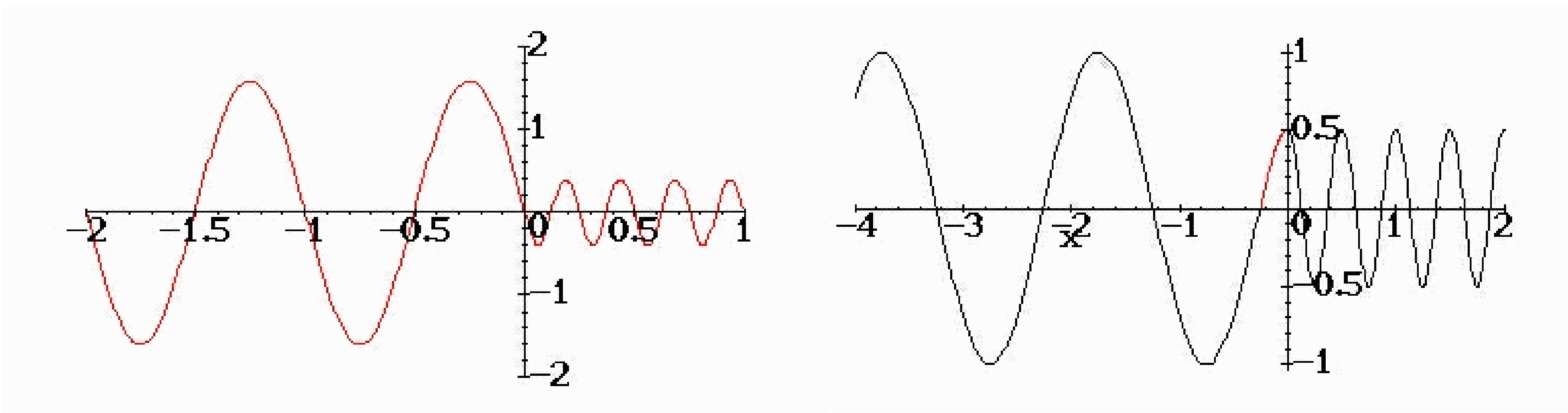


Q2b: ρ_L is the reflection coefficient at z = 0. Which (1-5) is the expression for **ρ at the distance of l from z = 0**?

1. $\rho(z=-l) = \rho_L \cdot e^{-j\beta l}$
2. $\rho(z=-l) = \rho_L \cdot e^{+j\beta l}$
3. $\boxed{\rho(z=-l) = \rho_L \cdot e^{-j2\beta l}}$
4. $\rho(z=-l) = \rho_L \cdot e^{j2\beta l}$
5. None of above



Topic 2: Smith chart & impedance matching



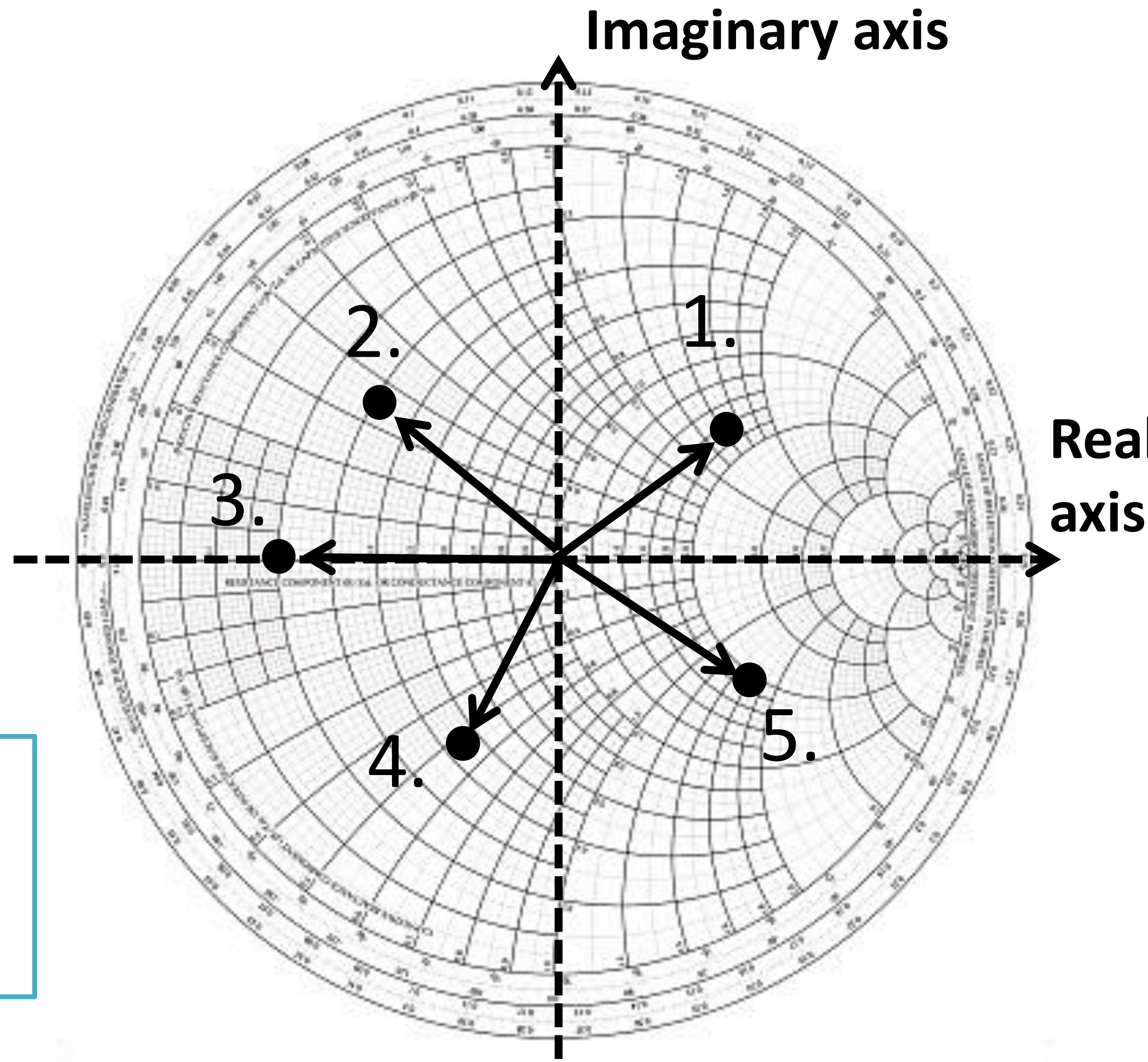
1. What can be observed in the figures?
2. Where do you see (partial) standing waves?
3. What for we need the impedance matching?
4. How the impedance matching is implemented through the matching network?
5. What for the Smith chart is needed?

Q3a: Which is the location of the voltage reflection coefficient ρ_L on the complex plane?

$$\rho_L = 0.5\angle -30^{o}$$

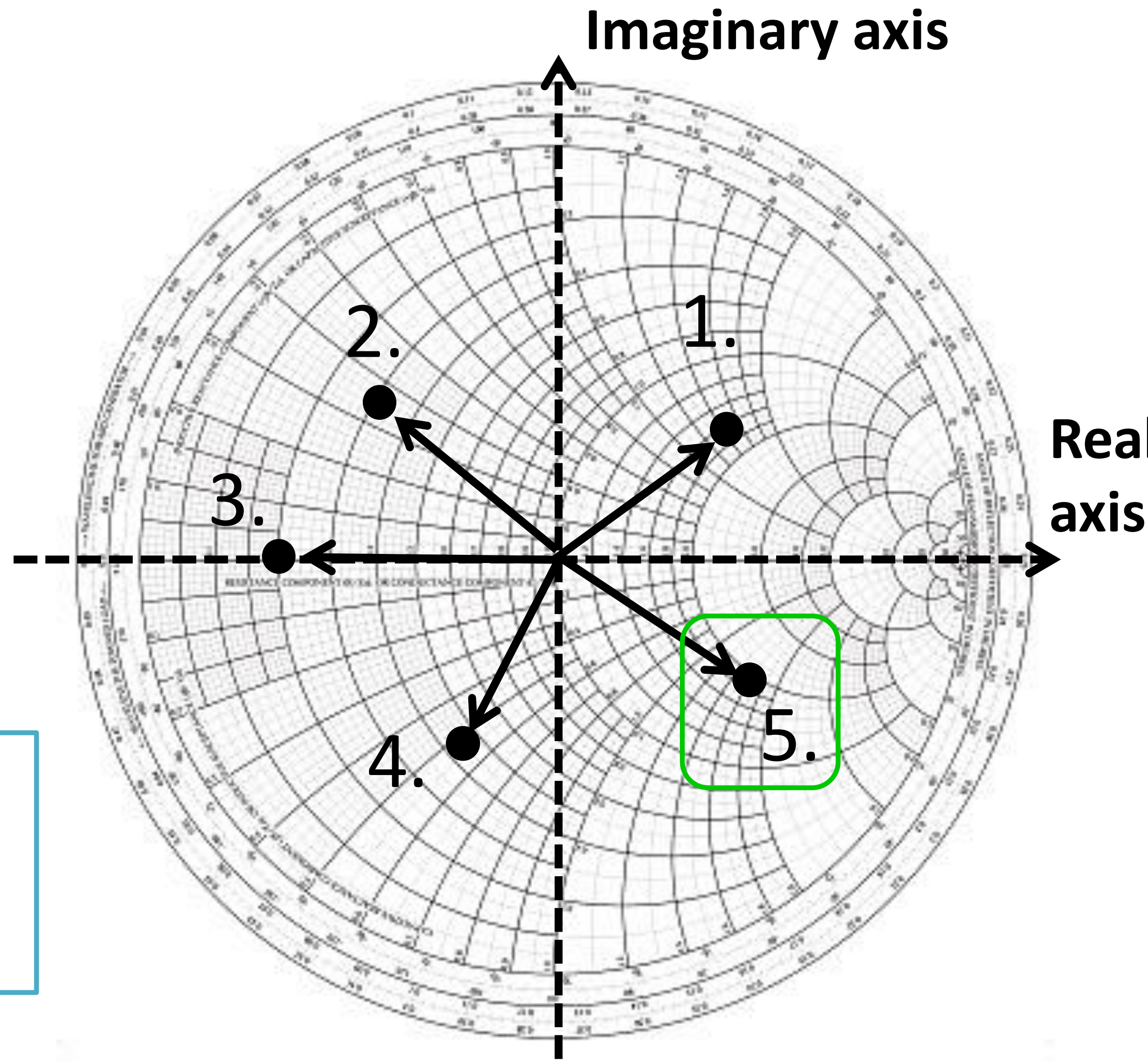
6. I don't know.

The Smith chart is a complex reflection coefficient plane.



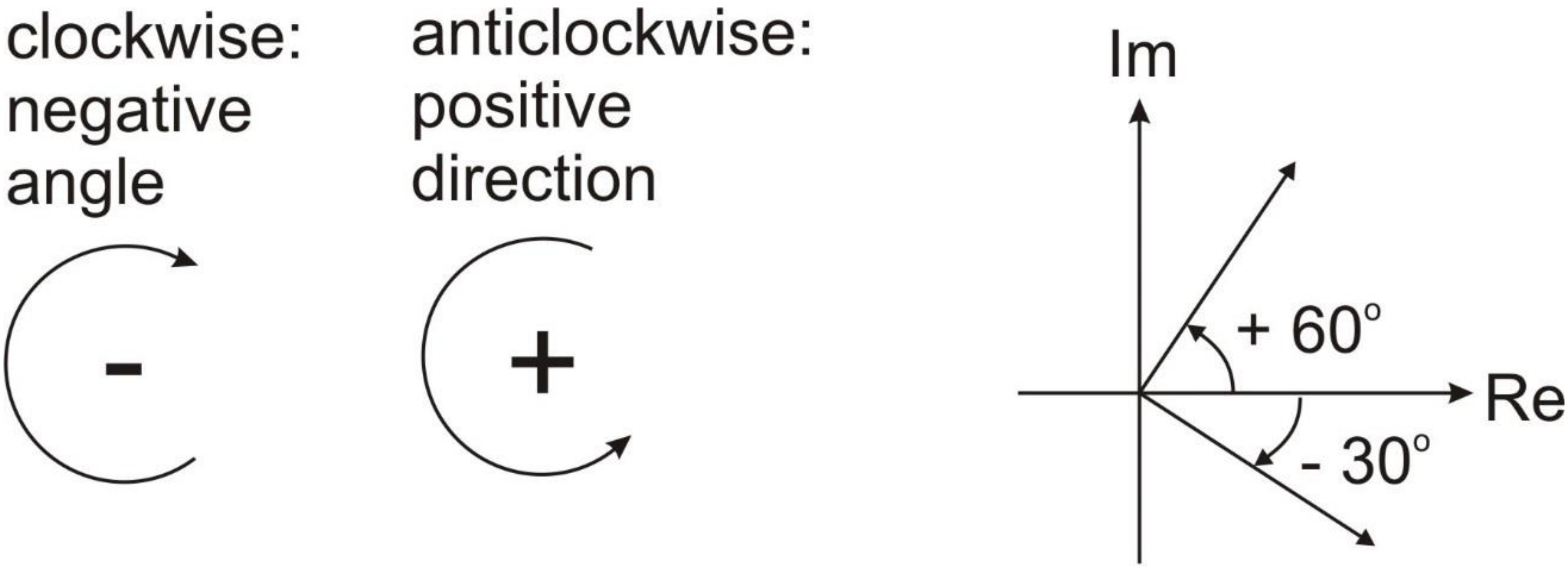
Q3b: Which is the location of the voltage reflection coefficient ρ_L on the complex plane?

$$\rho_L = 0.5\angle -30^{o}$$

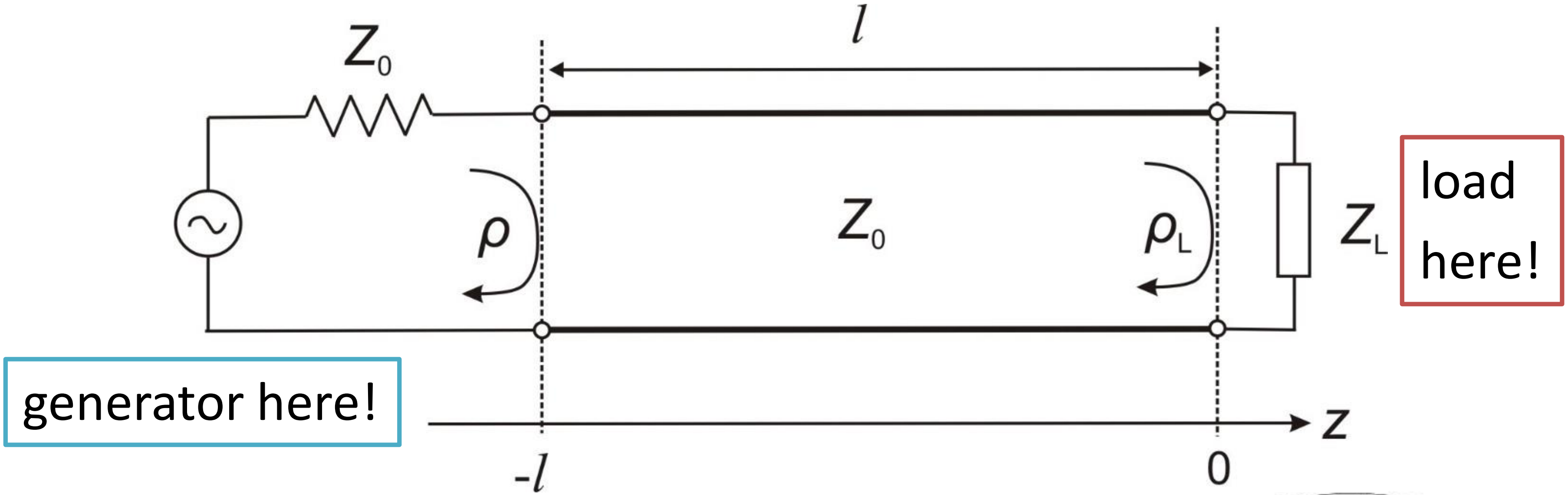


The Smith chart is a complex reflection coefficient plane.

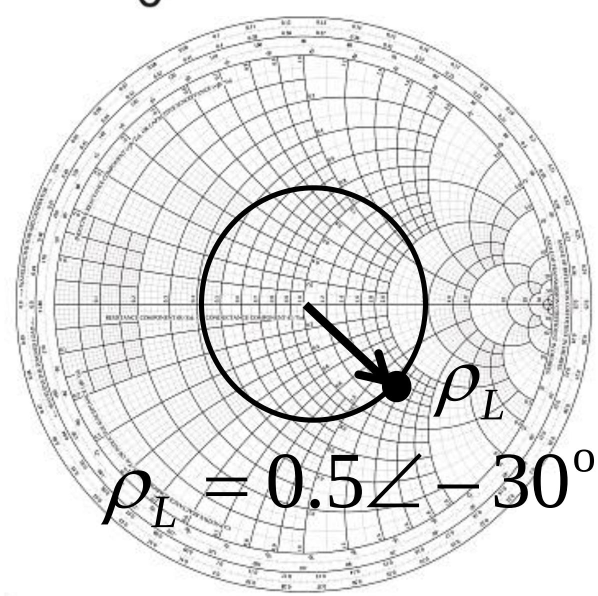
Rotation direction on the complex plane and the Smith chart



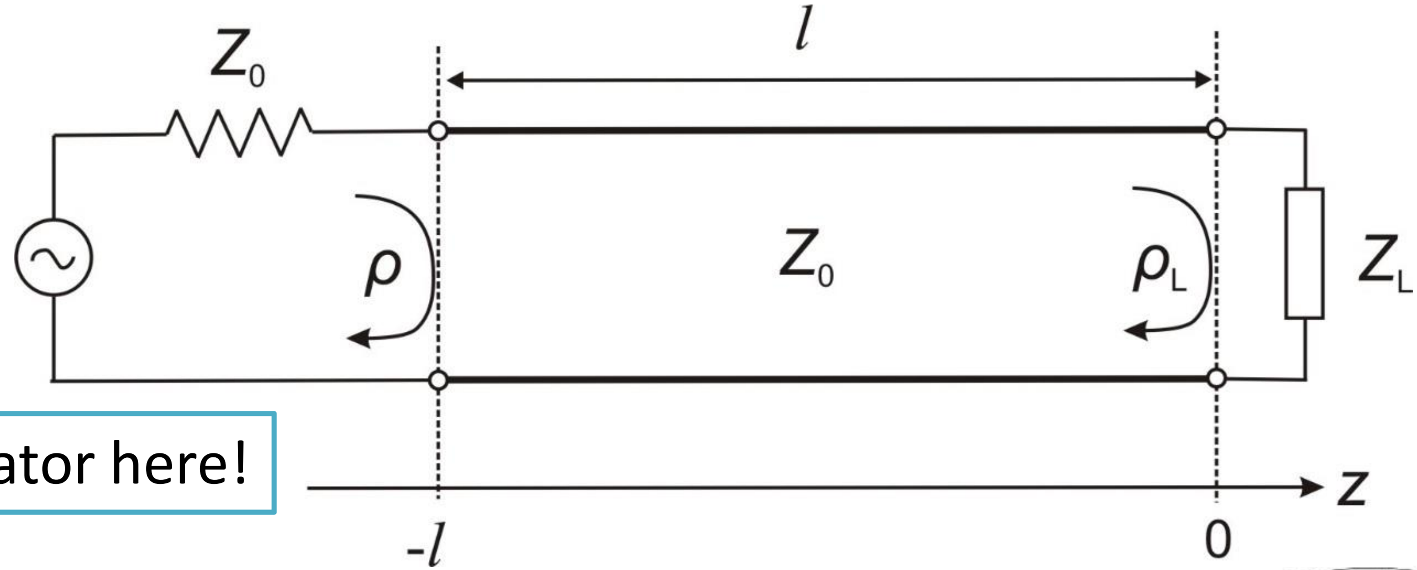
Q4a: The direction **from the load impedance towards the generator** is



1. always clockwise
2. always anticlockwise (i.e. counterclockwise)
3. either clockwise or anticlockwise; it depends on the location of the ρ_L on the Smith chart
4. direction of increasing reflection coefficient.
5. none of above
6. I don't know



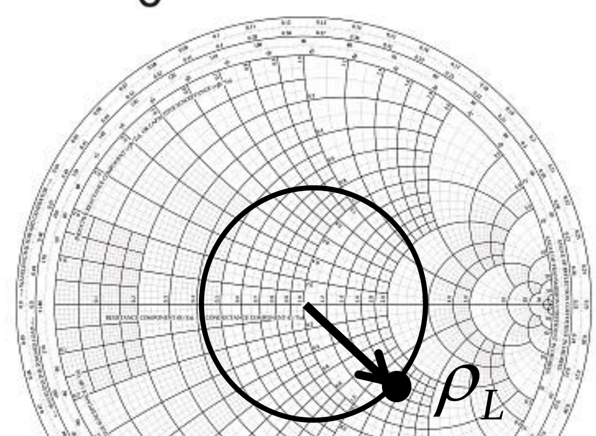
Q4b: The direction **from the load impedance towards the generator** is



load here!

generator here!

1. always clockwise
2. always anticlockwise (i.e. counterclockwise)
3. either clockwise or anticlockwise; it depends on the location of the ρ_L on the Smith chart
4. direction of increasing reflection coefficient.
5. none of above



$$\rho_L = 0.5\angle -30^o$$

Normalized impedance

On the Smith chart the impedance is **always normalized** to the ”reference impedance” Z_0.

The reference impedance Z_0 is 50 Ω (unless otherwise mentioned)

Normalized impedance (”small” letter, unitless)

”Non-normalized” impedance (capital letter, unit Ω)

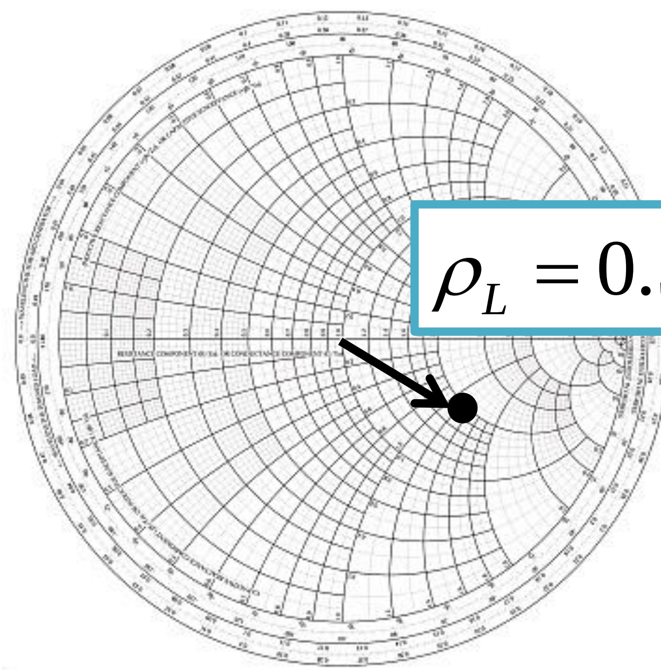
$$z_L = \frac{Z_L}{Z_0}$$

Reference impedance (typically 50 Ω)

Q5a: Read from the Smith chart, which is the **corresponding normalized impedance** z_L of ρ_L?

$$\rho_L = 0.5\angle -30^{\circ} = \frac{Z_L - Z_0}{Z_L + Z_0} \qquad z_L = \frac{Z_L}{Z_0}, Z_0 = 50\,\Omega$$

1. $z_L = 2.0 + j \cdot 1.3$
2. $z_L = 2.0 - j \cdot 1.3$
3. $z_L = 0.40 + j \cdot 2.0$
4. $z_L = 0.40 - j \cdot 2.0$
5. $z_L = 0.50 - j\,30$
6. I don't know



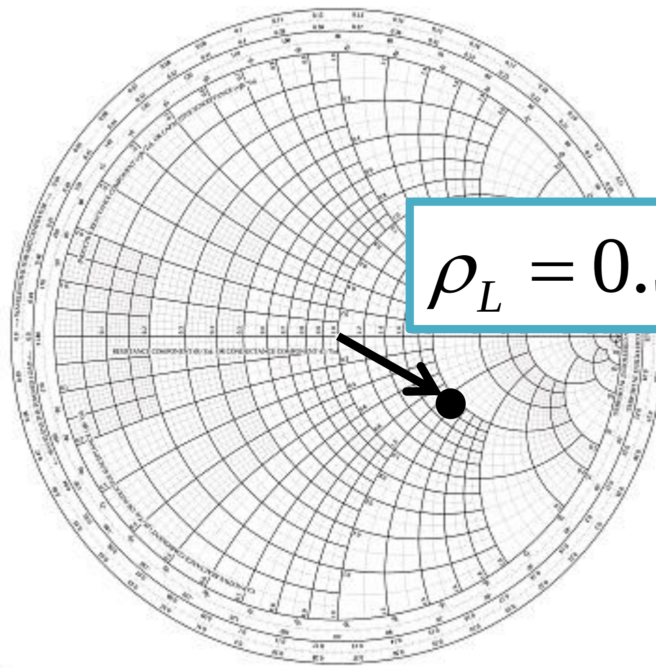
$\rho_L = 0.5\angle -30^{\circ}$

The Smith chart is also normalized impedance scale

Q5b: Read from the Smith chart, which is the **corresponding normalized impedance** z_L of ρ_L?

$$\rho_L = 0.5\angle -30^o = \frac{Z_L - Z_0}{Z_L + Z_0} \qquad z_L = \frac{Z_L}{Z_0}, Z_0 = 50\,\Omega$$

1. $z_L = 2.0 + j\cdot 2.0$
2. $\boxed{z_L = 2.0 - j\cdot 1.3}$
3. $z_L = 0.40 + j\cdot 0.5$
4. $z_L = 0.50 - j\cdot 2.0$
5. $z_L = 0.50 - j\ 30$



$\rho_L = 0.5\angle -30^o$

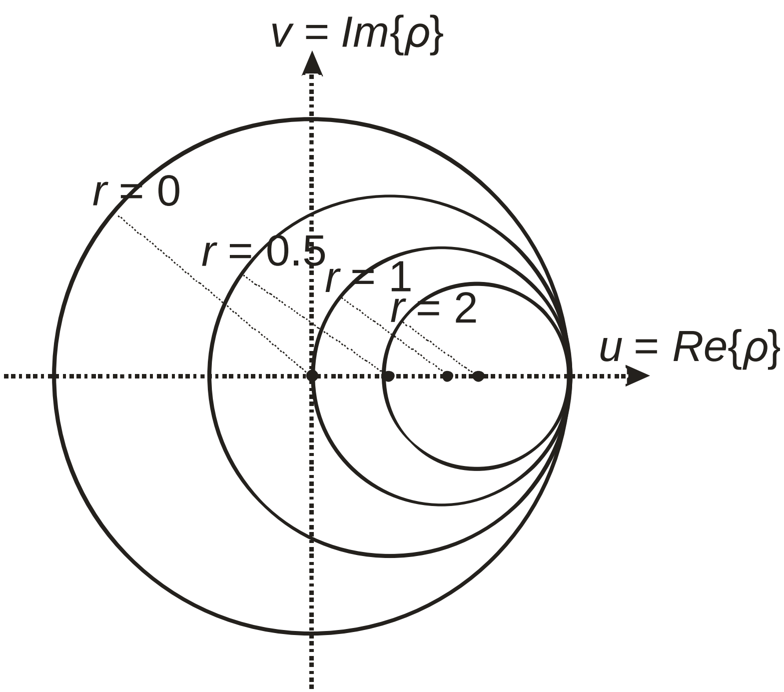
The Smith chart is also normalized impedance scale

The Smith chart is normalized impedance scale on the complex reflection coefficient plane

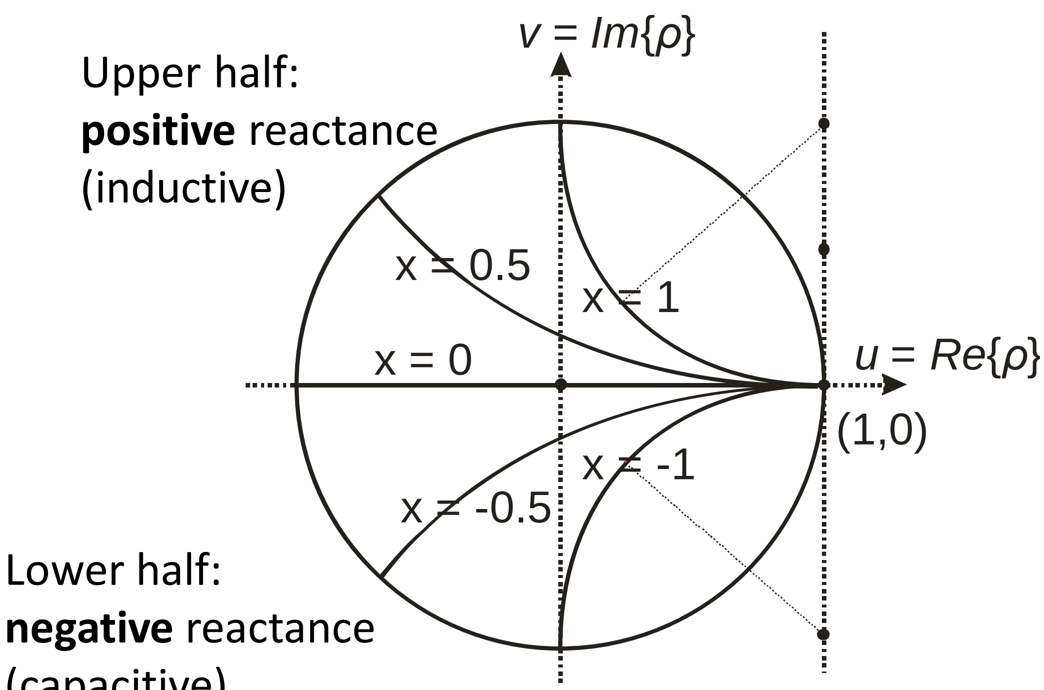
All mathematical derivation on one line:

$$\rho_L = u + \mathrm{j}v = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{r + \mathrm{j}x - 1}{r + \mathrm{j}x + 1} \Leftrightarrow 1:\left(u - \frac{r}{r+1}\right)^2 + v^2 = \frac{1}{(r+1)^2} \text{ and } 2:\ (u-1)^2 + \left(v - \frac{1}{x}\right)^2 = \frac{1}{x^2}$$

1: constant resistance (r) circles:



2: constant reactance (x) circles:

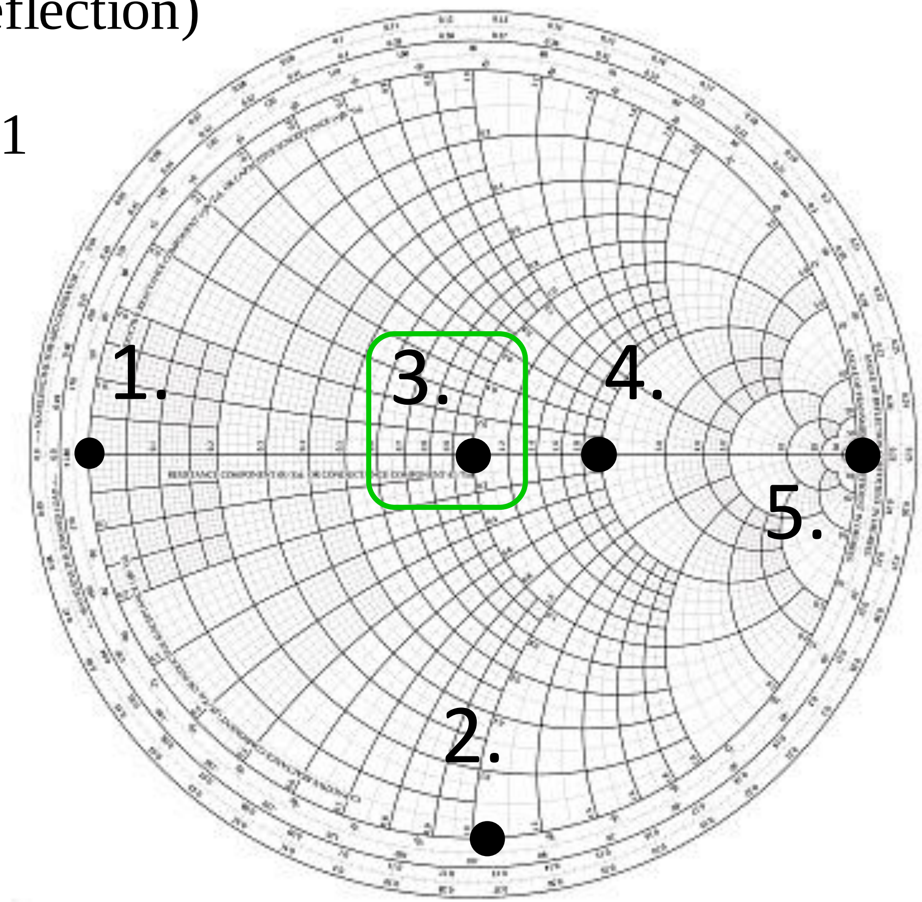


Q6: Which of the points (1-5) corresponds to the **matched** load impedance?

matched means : $\rho_L = 0$ (no voltage reflection)

$$\rho_L = \frac{Z_L - Z_0}{Z_L + Z_0} = 0 \Leftrightarrow Z_L = Z_0 \Leftrightarrow z_L = 1$$

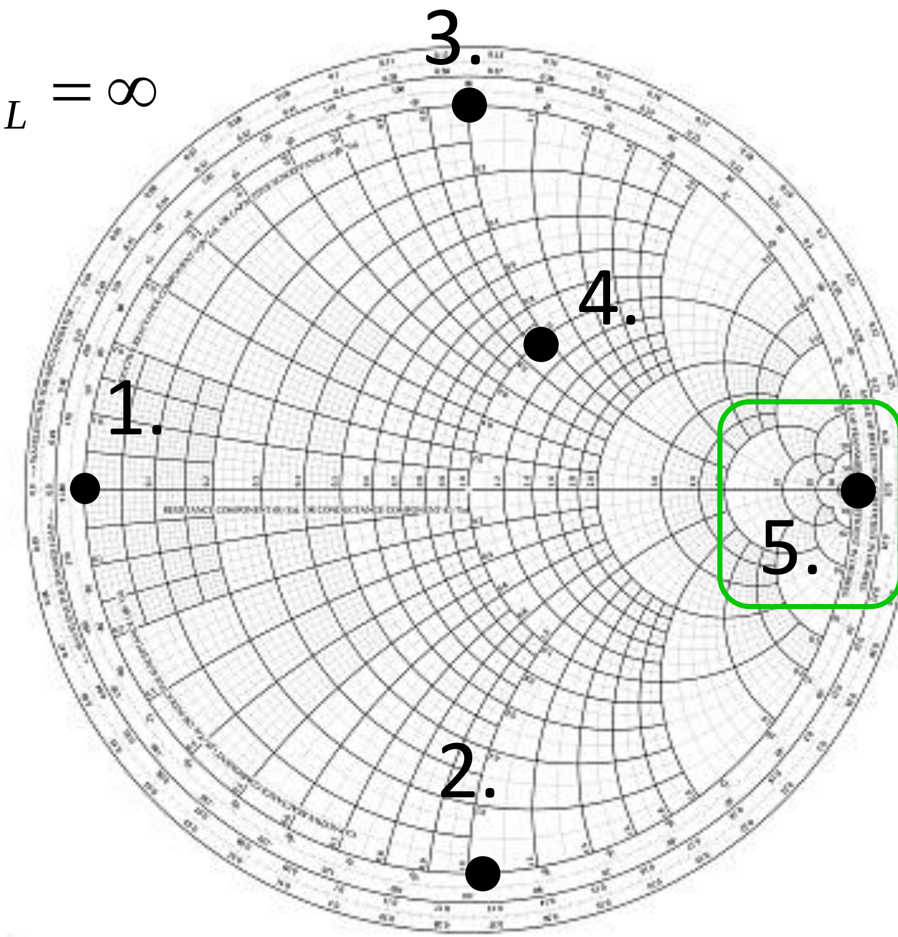
6. I don’t know.

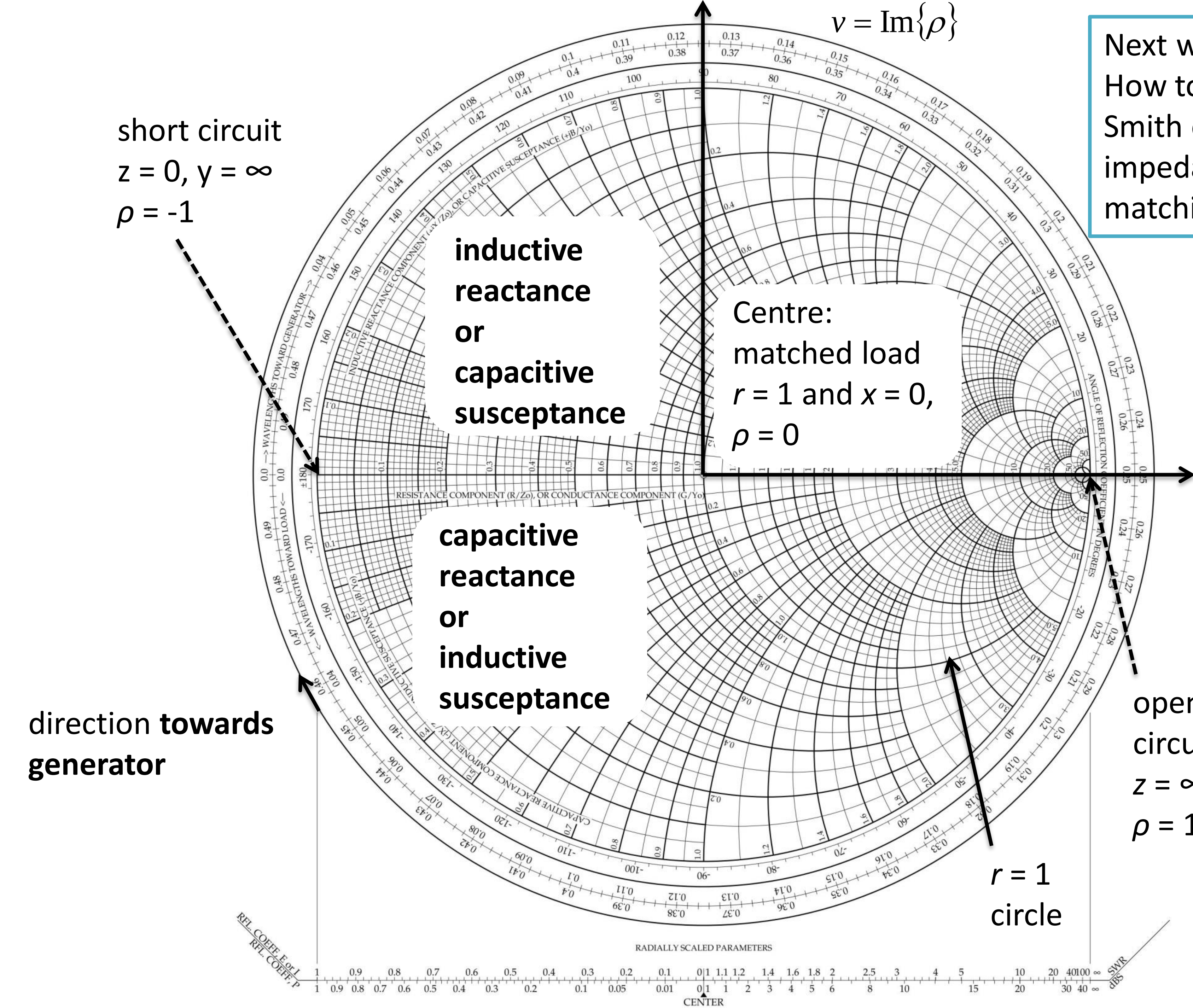


Q7: Which point (1-5) corresponds to "**open circuit**" impedance?

$$\rho_L = \frac{Z_L - Z_0}{Z_L + Z_0} \qquad \text{open circuit} : Z_L = \infty$$

6. I don't know.





Next week:
How to use the Smith chart in impedance matching

Topic 2: Smith chart & impedance matching

The Smith chart is **not** only for designing the matching circuits, but oftentimes it is actually used for interpretation of the impedance or reflection coefficient behaviour as a function of the frequency.