Lab Section (Day/Time)______________________

Names of Student with ID# 2022214880

Student Li Xianzhe ________ **Instructor signature** ______________________

NAU + CQUPT

EE 188 Lab 8

Complex Power in AC Circuits

Introduction:

In **passive AC circuits** with both reactive and resistive elements (inductors, capacitors and resistors), **Power** must be **complex-valued** in order to account for the energy expended in actual work (Watts) and that which is tied-up in the maintenance of expanding and collapsing electric and magnetic fields in the reactive elements (Vars).

Complex Power in sinusoidal signals is best accounted for by using **complex-valued** notation.

The formula for **complex power S** in a circuit with a current and voltage at a port is given by

$$\mathbf{S} = \tfrac{1}{2}\,\mathbf{V}\mathbf{I}^* \text{ (VA)}$$

where $\mathbf{V} = V\underline{/\theta_v}$ is the **voltage phasor** (V)

$\mathbf{I} = I\underline{/\theta_i}$ is the **current phasor** (A)

Phase angles $\underline{/\theta_v}$ and $\underline{/\theta_i}$ **are with respect to a reference** 0^0 **elsewhere.**

Note that the phasors are **peak values** and **not rms values** in this expression. If **rms values** are used, the ½ factor would already be accounted for. For this exercise, we shall stick with **peak values**.

In **rectangular** and **polar** forms **S** is also expressed by

$$\mathbf{S} = \mathbf{P} + j\mathbf{Q}$$

where **P = real power** (Watts)

Q = reactive power (Vars)

$$\mathbf{S} = S\underline{/\theta_p}$$

where S = **apparent power** (VA)

θ_p = **power angle** = $(\theta_v - \theta_i)$ (electrical degrees)

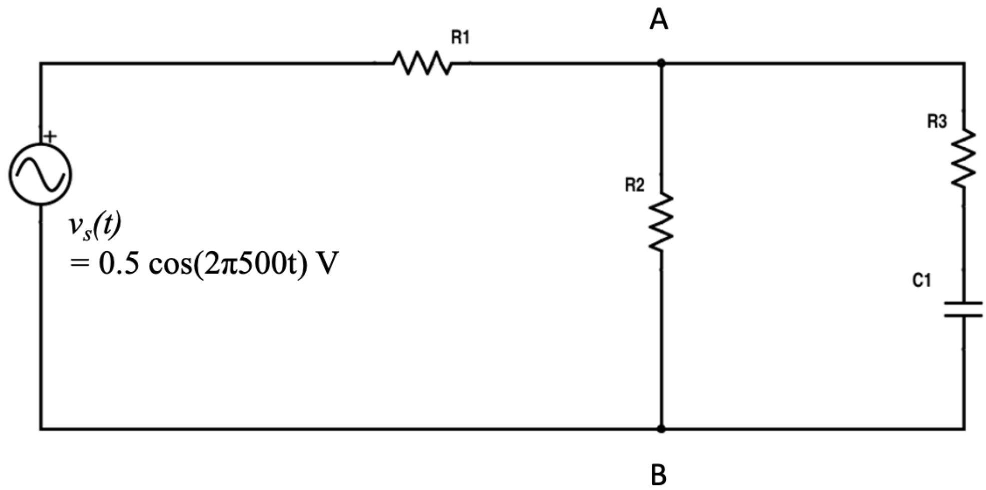
The factor $\cos(\theta_p)$ is defined as the **power factor** (**PF**), and is an indication of the amount of available **real power** (of the **apparent power** S) that can be **delivered** or **absorbed** by the circuit at the input.

Procedure:

Set-up the following circuit, adjusting the function generator to

$$v_s(t) = 0.5\cos(2\pi 500t) \text{ volts.}$$

<u>Note</u> that the **load** is between nodes **A** and **B**, which is **R_2 in parallel with the R_3 - C_1** branch.



Measure and note **the exact resistor and impedance values:**

$R_1 = 2.7k\Omega$ => _____2701.7Ω__________**(measured)**
$R_2 = 3.6k\Omega$ => _____3693.3Ω__________**(measured)**
$R_3 = 4.3k\Omega$ => _____4288.6Ω__________**(measured)**
$C_1 = 0.1\mu F$ → $Z_C = -j/\omega C$ = _____-j3183.1Ω___

<u>Activities A, B & C</u>

A. Phasor, Impedance & Power Calculations:

1) Calculate **Z_{Load}** (show all steps, as done in lectures)
2) Calculate **Z_T**.
3) Calculate total current **I_T**.
4) Using **voltage division**, calculate **V_{Load}**.
5) Calculate total complex power **S_T**
6) Calculate load complex power **S_{Load}.**
7) Show that the **total complex power** equals the **load complex power** + the **real power** in resistor **R_1** (which will also have to be calculated).

1). $Z_L = (R_3 + Z_{C1}) \parallel R_2 = \dfrac{(4300 - j3183.1) \times 3600}{(4300 - j3183.1) + 3600} = 2188.6 - j568.7\,\Omega$

2). $Z_T = Z_L + R_1 = 2188.6 - j568.7 + 2700 = 4888.6 - j568.7\,\Omega$.

3). $I_T = \dfrac{V_S}{Z_T} = \dfrac{0.5\angle 0^\circ}{4888.6 - j568.7} = 1.02 \times 10^{-4} \angle 6.64^\circ\ A$.

4). $V_L = V_S \times \dfrac{Z_L}{Z_T} = 0.5\angle 0^\circ \times \dfrac{2188.6 - j568.7}{4888.6 - j568.7} = 0.23\angle -7.99^\circ\ V$.

5). $S_T = \dfrac{(V_{Srms})^2}{Z_T} = \left(\dfrac{0.5}{\sqrt{2}}\right)^2 / (4888.6 - j568.7) = 2.52 \times 10^{-5} + j2.93 \times 10^{-6}\ VA$.

6). $S_L = \dfrac{(V_{Lrms})^2}{Z_L} = \left(\dfrac{0.23}{\sqrt{2}}\right)^2 / (2188.6 - j568.7) = 1.13 \times 10^{-5} + j2.94 \times 10^{-6}\ VA$.

7). $P_{R1} = (I_{Trms})^2 R_1 = \left(\dfrac{1.02 \times 10^{-4}}{\sqrt{2}}\right)^2 \times 2700 = 1.4 \times 10^{-5}\ W$.

$S_L + P_{R1} = 2.53 \times 10^{-5} + j2.94 \times 10^{-6}\ VA = S_T$.

B. Measurements:

Using both channels of your oscilloscope,

1) Measure the **input voltage signal** and use it as **reference 0^0**
   → phasor $\mathbf{V_s} = \mathbf{0.5\underline{/0^0}}$ (volts)

2) Measure the **load voltage signal**:

   $\mathbf{V_L}$ = $\underline{\ 0.237\angle - 7.92°\text{V}\ }$ **(phasor)**

   and use it to **calculate $\mathbf{S_{Load}}$** and **$\mathbf{S_T}$** of **part A** above.

   $S_L = \dfrac{|V_{Lrms}|^2}{Z_L} = \left(\dfrac{0.237}{\sqrt{2}}\right)^2 / (12188.6 - j5068.7) = 1.2\times10^{-5} + j3.12\times10^{-6}$ VA

   $S_T = S_L + P_{R1} = 1.2\times10^{-5} + j3.12\times10^{-6} + 1.4\times10^{-5} = 2.6\times10^{-5} + j3.12$ VA.

→ **Clearly show all your steps and calculations, as done in class!**

C. Drawing graphs:

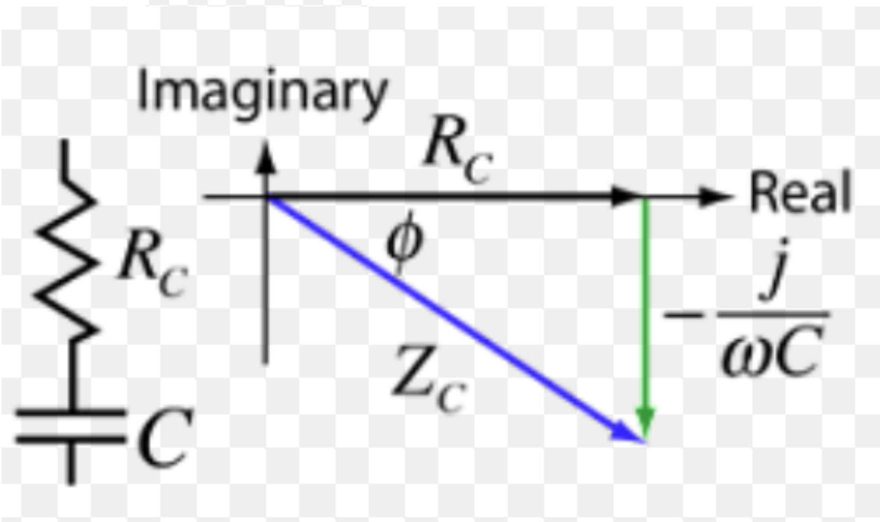
Plot on the Complex (Re, Im) plane the 3 <u>separate</u> graphs below:

1) All **Impedance Vectors**, showing that they **add vectorally**
   $\mathbf{Z_T} = Z_T\underline{/\varphi_T} = \mathbf{Z_{Load}} + \mathbf{R_1}$

   → **All units are in Ohms (Ω)**

Example – drawing impedances

$$Z_C = R_C - \frac{j}{\omega C}$$

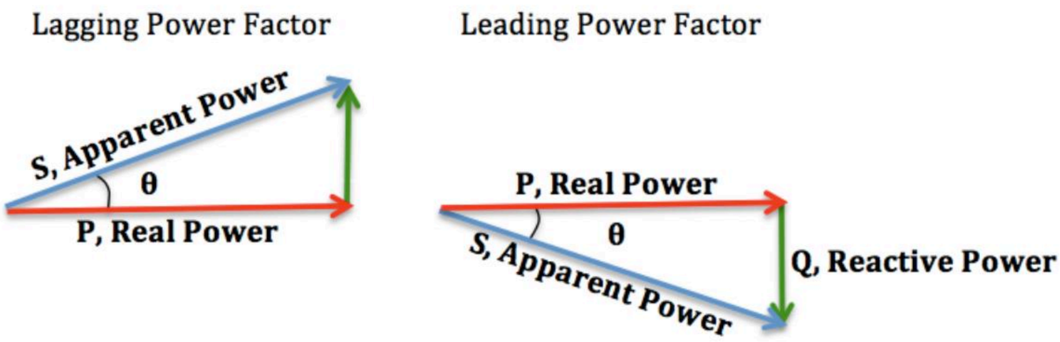


2) The **Complex Power Vectors**, showing that they **add vectorally**

$$S_T = S_L + P_{R1} = P_T + jQ_T$$

➔ **All units are <u>Power units</u> (VA, Vars & Watts)**

Example – the power vector



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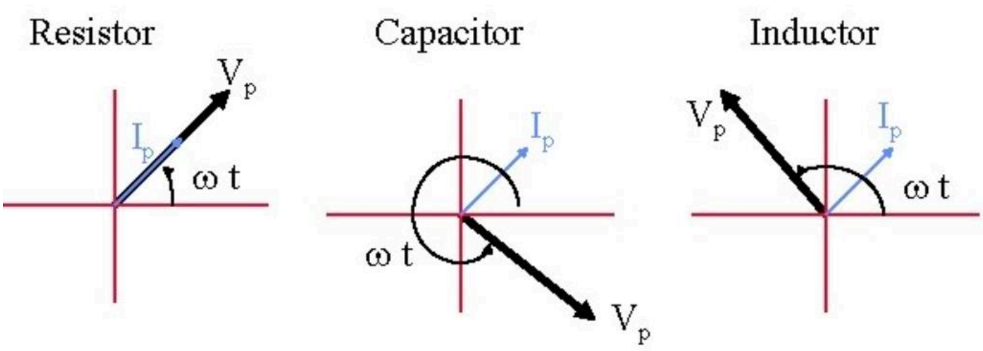
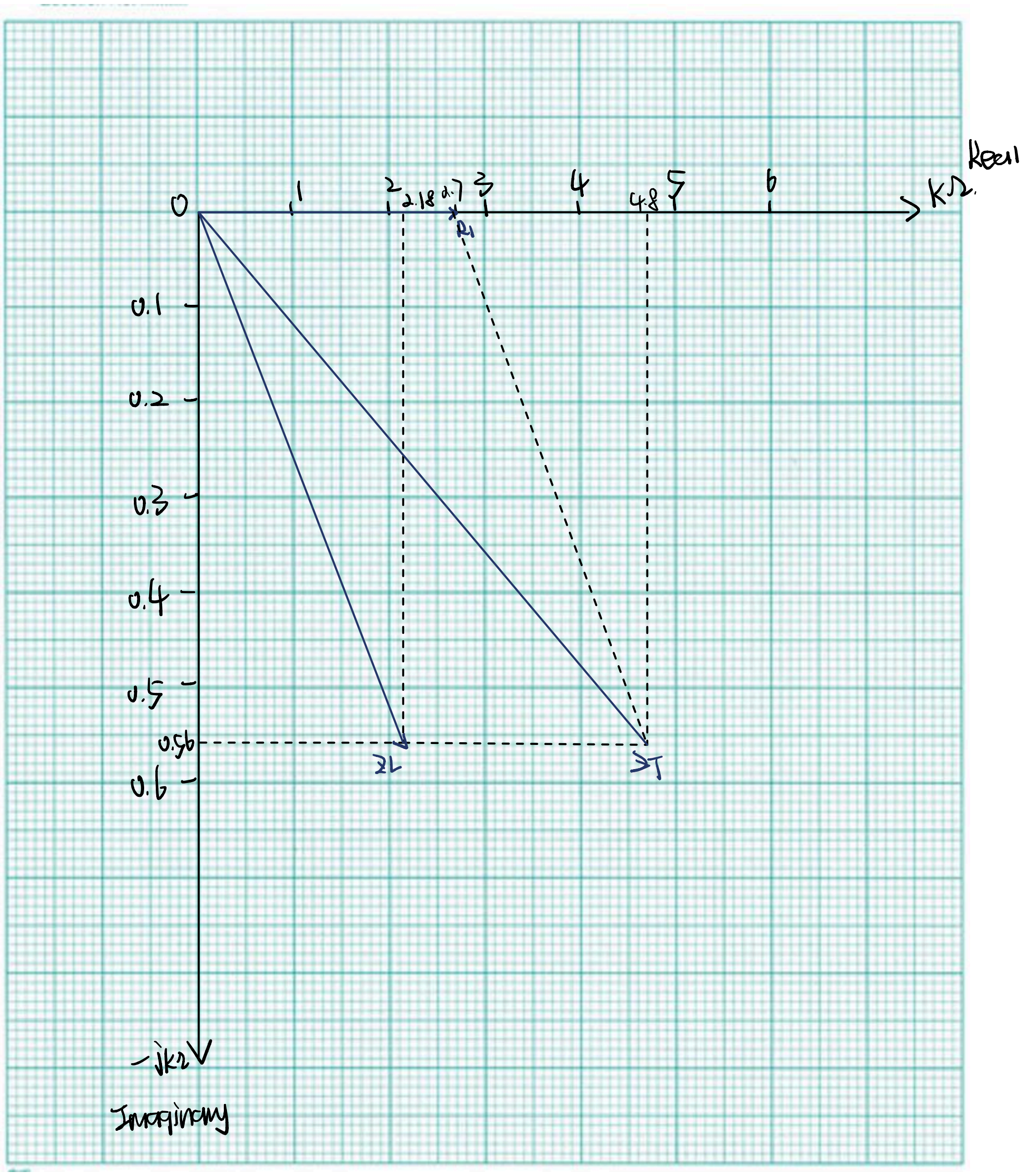
3) The **Phasor Vectors** for V_S = **0.5/<u>0</u>^{0} (ref)**, I_T and V_L.

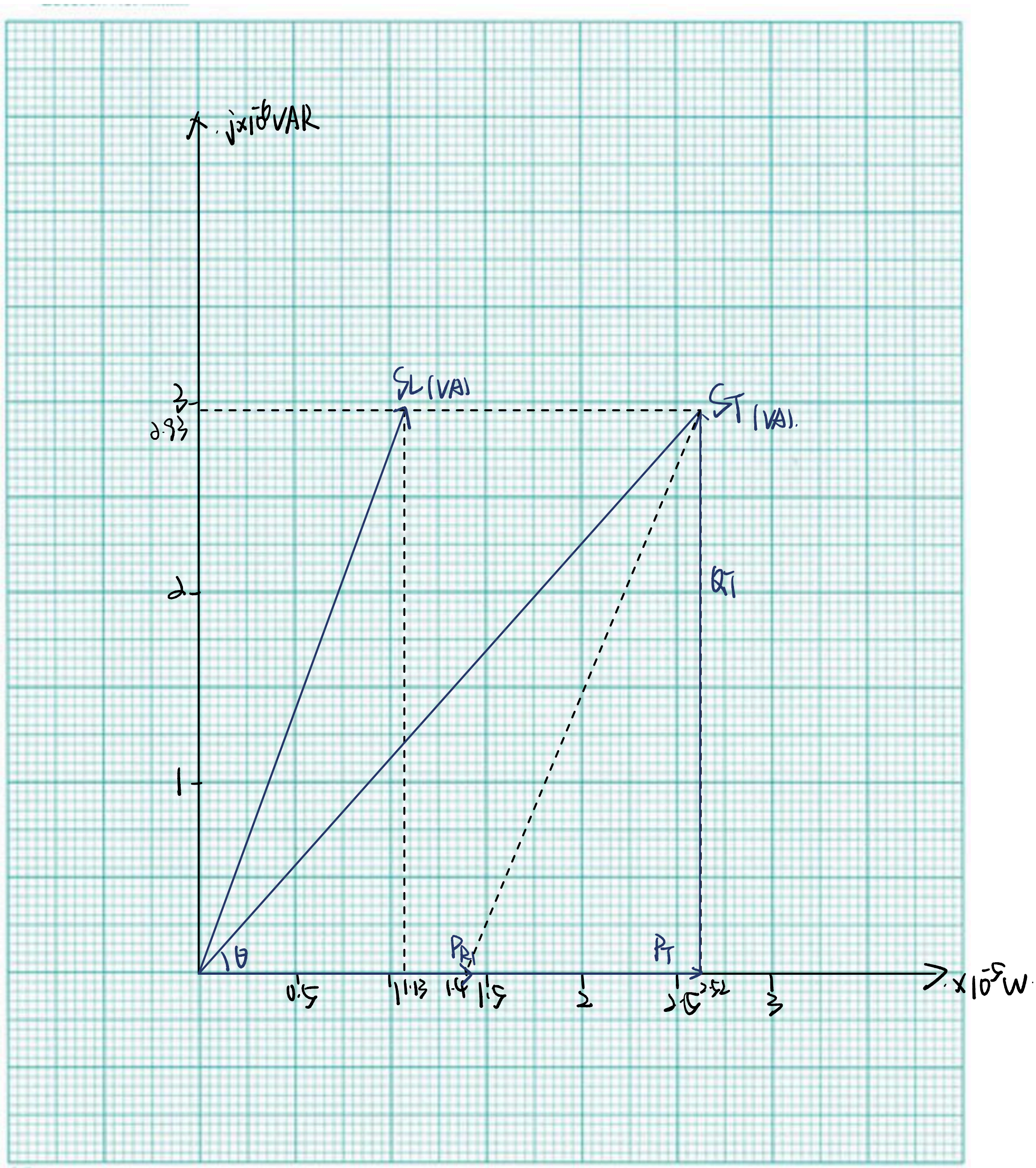
Example – drawing phasors



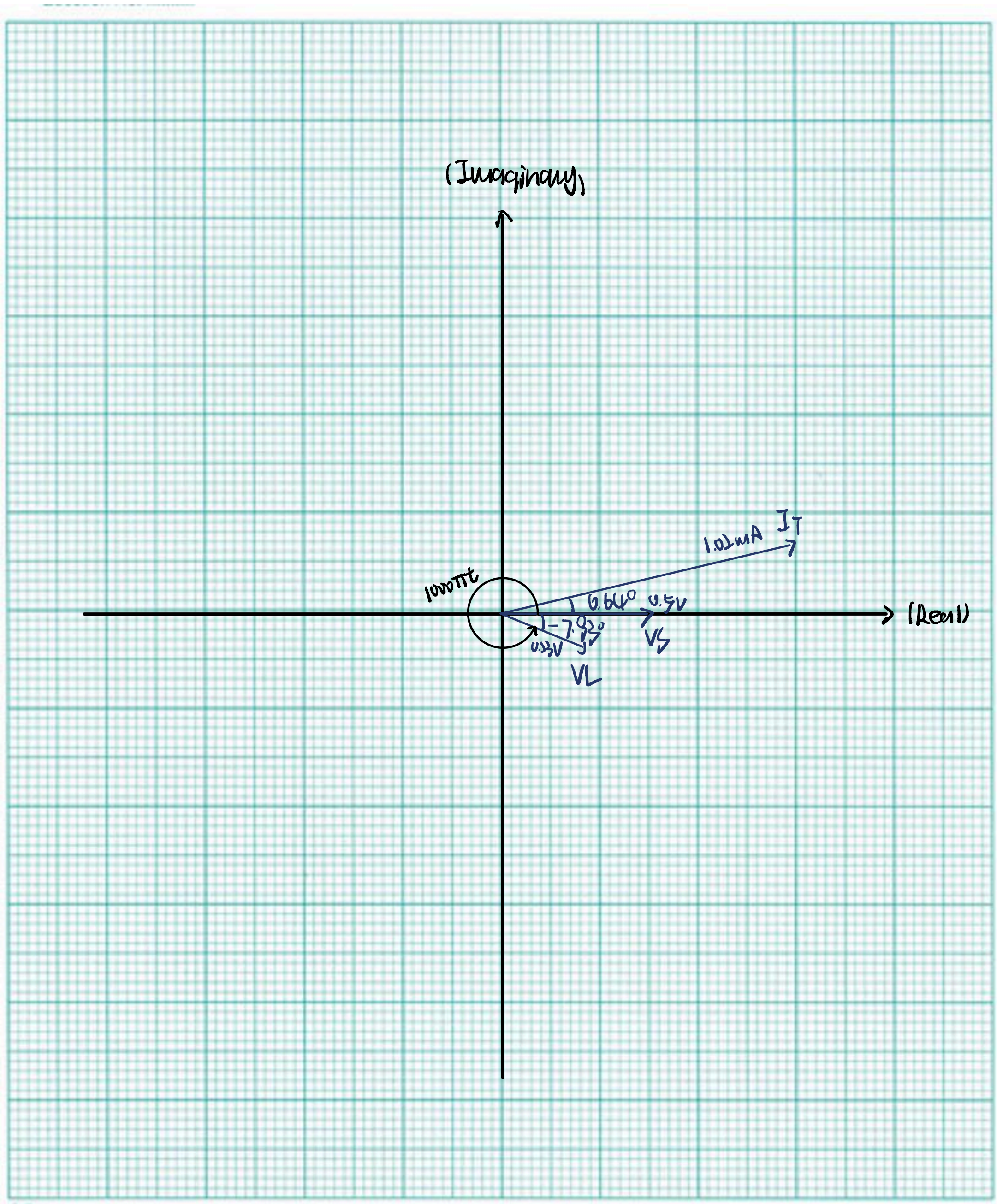
Note: You will have to put in the proper scales and units for x- and y-axis in each of the complex-plane graphs below



Impedance (kΩ)



<u>Complex Power</u> (VA, Watts, Vars)



<u>Phasors</u> (volts & mA)

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