EN811100 LINEAR CIRCUIT ANALYSIS
Quiz 5

Instructions:

There are 5 problems. Full scores require all 5 problems solved.

The submission is through Autolab (https://autolab.en.kku.ac.th).

The submission system allows an infinite number of submissions, but due to performance drop from heavy load, to lessen the unnecessary load a version penalty is implemented. A student can submit as many as 5 versions without any penalty. After that, each version over 5 is subjected to 5% penalty.
Due date is shown on the system.
Late submission will be penalized 50%.

How to write an acceptable answer

Student's answers will be graded with policy: `lca2022` (tolerance < 0.001).
Note: tolerance is the largest difference the grader allows when tests student's answer. It may be less straightforward for option `p` or `P`. (See below) Therefore, students are advised to answer with higher precision than 0.001.

`Grading option: e` (engineering prefix) means (1) text must be exactly matched. (2) Each number must be well spaced (there is space before and after a number). (3) A number can be written in a regular format, using engineering prefix or scientific notation.

E.g., Given reference: `vx = -12.4 V; ix = 18.5 mA`

```
vx = -12.4 V; ix = 18.5m A        GOOD FORMAT /
vx = -12.4 V; ix = 18.5 mA        GOOD FORMAT /
vx = - 12.4 V; ix = 0.0185 A      GOOD FORMAT /
vx = -12.4 V; ix = 18.5e-3 A      GOOD FORMAT /
vx = - 12.4009 V; ix = 0.0185 A   GOOD FORMAT / (Still within tolerance)
vx = - 12.401 V; ix = 0.0185 A    GOOD FORMAT × (Over tolerance)
vx = -12.4 V; ix = 18.5 e-3 A     BAD FORMAT! ×
vx = -12.4V; ix = 18.5mA          BAD FORMAT! ×
vx =-12.4V; ix =18.5mA            BAD FORMAT! ×
vx =-12.4V ix =18.5mA             BAD FORMAT! ×
vx =-12.4V. ix =18.5mA            BAD FORMAT! ×
```

`Grading option: l` (linear equation) means a linear equation must be written with each term well-spaced.
Each term can be written as a constant, a single variable, or a coefficient-variable pair. A coefficient-variable pair must start with coefficient following by a space then a variable. Constants and coefficients can be written in a regular format, using engineering prefix or scientific notation.
E.g., given reference: `-10 + v1 + 4 i2 = 0`

```
- 10 + v1 + 4 i2 = 0                 GOOD FORMAT /
v1 + 4 i2 = 10                       GOOD FORMAT /
2 v1 + 8 i2 = 20                     GOOD FORMAT /
2k v1 + 8k i2 = 20k                  GOOD FORMAT /
2e3 v1 + 8e3 i2 = 20e3               GOOD FORMAT /
8e3 i2 = 20e3 - 2e3 v1               GOOD FORMAT /
- 10 + 2 v1 + 4 i2 = v1              GOOD FORMAT /
- 10 + v1 + 4.0009 i2 = 0            GOOD FORMAT / (Still within tolerance)
- 10 + v1 + 4.001 i2 = 0             GOOD FORMAT × (Incorrect)
- 10 + v1 + 3.999 i2 = 0             GOOD FORMAT × (Incorrect)
- 10 + 4 i2 = 0                      GOOD FORMAT × (# terms mismatches)
- 10 + 4 i2 + v1 + v2 = 0            GOOD FORMAT × (# terms mismatches)
- 10 + 4 i2 + v2 = 0                 GOOD FORMAT × (Miss v1)
- 10 + 4 i2 + v1 = v1                GOOD FORMAT × (Incorrect)
- 10 + 4 i2 + v1 = v1                GOOD FORMAT × (Incorrect)
-10e-8 + 1e-8 v1 + 4e-8 i2 = 0       GOOD FORMAT × (Magnitude too small)
- 10 + v1 + 4i2 = 0                  BAD FORMAT! ×
-10+v1+4i2 = 0                       BAD FORMAT! ×
- 10 + v 1 + 4 i 2 = 0               BAD FORMAT! ×
- 1 0 + v1 + 4 i2 = 0                BAD FORMAT! ×
```

`Grading option: p` (python code) means the answer is interpreted as a python code and it will be run as a python code. The answer will be separated into 2 parts: prefix and the code.
E.g., `v2(t) = 8 - 6*exp(-t/0.02)` will be separated into prefix `v2(t)` and python code `8 - 6*exp(-t/0.02)`. The pycode will be run using lambda function assignment with all standard python functions and math functions, i.e.,
the code must work when put into a context such as:

```
from math import *

student_fn = lambda t: 8 - 6*exp(-t/0.02)

for argin in testargins:   # testargins: list of values, e.g., [0.001, 0.003, 0.006]
    val = student_fn(argin)
```

Note all math functions are imported directly. This mean:
`exp(t)` is evaluable, but `math.exp(t)` is NOT.
The prefix must match what the question asks exactly. The python code part is student's answer.
E.g., given a correct answer is `v2(t) = 8 - 6*exp(-t/0.02)`,

```
v2(t) = 8 - 6*exp(-t/0.02)           GOOD FORMAT /
```

```
v2(t) = 8 - 6*exp(-50*t)            GOOD FORMAT ✓
v2(t) = - 6*exp(-50*t) + 8          GOOD FORMAT ✓
v2(t) = 6*exp(-50*t) + 8            GOOD FORMAT × but wrong!
v2(t) = 8 - 6 exp(-t/0.02)          BAD! × syntax error

v(t) = 8 - 6*exp(-t/0.02)           BAD FORMAT! × QID not found
v2(t) : 8 - 6*exp(-t/0.02)          BAD FORMAT! × no QID specified
v2(t) = 8 - 6*e^(-t/0.02)           BAD! × unsupported operand
v2(t) = 8 - 6*exp(-time/0.02)       BAD! × 'time' is not defined
```

Note that difference in the answer is checked through the evaluation of the function, not in a symbolic form. E.g., an expected answer of function "`f(x) = 0.1*x`" and student's answer of "`f(x) = 0.101*x`" will be over the tolerance when tested with `x = 10` (or any `x > 1`). With `x = 10`, reference is `1`, evaluation of student's answer is `1.01` and the difference is 0.01, which is over the tolerance 0.001. Using multiple digits more precise than the test tolerance is highly recommended.

`Grading option: P` (python code as an answer as well as complex as a reference) is similar to `p` (python-code mode), but it also not allows a complex number. For LCA, we will reserve this mode for a complex number as an answer.

E.g., Given reference: **`Z = 400 + 300j`**

```
Z = 400 + 300j              GOOD FORMAT ✓
Z = 400 +     300j          GOOD FORMAT ✓ (extra space)
Z =400 + 300j               GOOD FORMAT ✓ (space)
Z =400+ 300j                GOOD FORMAT ✓ (space)
Z =400+300j                 GOOD FORMAT ✓ (space)
Z = 0.4e3 + 0.3e3j          GOOD FORMAT ✓ (sci. notation)
Z = 300j + 400              GOOD FORMAT ✓ (order)
Z = 400.0007 + 299.9993j    GOOD FORMAT ✓ (Still within tolerance)
Z = 400.0009 + 299.9991j    GOOD FORMAT × (Over tolerance)
Z = 400 + j300              BAD FORMAT! × (!order)
Z = 400 + 300 j             BAD FORMAT! × (!space)
Z = 400 + 0.3Kj             BAD FORMAT! × (!engineering prefix)
```

Remark! Student's "`Z = 0 + 300j`" can match reference "`Z = 300j`" without any problem. The complex-number answer (or whatever on the left side of the '=' sign) is a python code.

How to read Autograder feedback

Example

```
lca2022: report mode: Hint ; tol: 0.001 ; grading mode: leppP
lca2022: # reference lines: 5
lca2022: # submitted lines: 5
lca2022: feedback: line 0
lca2022: * student    : - V1 + 100 i2 + Vx - 12.002 = 0
lca2022: * feedback: Linear: incorrect
lca2022: feedback: line 1
lca2022: * student    : i1 = 23.14e-3 A; V1 = 12.402 V
lca2022: * difference: ______________________######
lca2022: * student    : Q1: i(t) = 0.3*cos(100*t + -1.)
lca2022: * feedback: over tolerance
lca2022: * student    : Q2: VB(t) = 3*t
lca2022: * feedback: QID not found
lca2022: * student    : Q3: S  2 + 4j
lca2022: * feedback: No QID specified
```

`tol: 0.001 ; grading mode: leppP`

`tol: 0.001` means all numbers are graded with tolerance 0.001.
`grading mode: leppP` means 5 lines are expected in the answer.

- `l` means the (first) line is graded as a linear equation.
- `e` means the (second) line is graded in an engineering prefix mode.
- `p` means the (third and fourth) line (after '=') is graded in a python mode.
- `P` means the (fifth) line is graded in a python mode against python code reference. (LCA reserves this for a complex number as an answer.)

`- V1 + 100 i2 + Vx - 12.002 = 0` is the submitted answer.
`Linear: incorrect`
means that this equation is incorrect.

`i1 = 23.14e-3 A; V1 = 12.402 V`
`______________________######`
means that the first mismatch is found here on the 12.402.

`Q1: i(t) = 0.3*cos(100*t + -1.)`
`over tolerance`
means that the function is in a good format, but it is either incorrect or its precision is over the tolerance.

`Q2: VB(t) = 3*t`
`QID not found`
means that the right side (of the '=') may be misspelled, e.g., there might be a typo in `Q2: VB(t)`. Letter case is a common mistake, check if it is `Q2: Vb(t).`

`Q3: S  2 + 4j`
`No QID specified`
means that the QID mark (i.e., ‘`=`’ for LCA) is missing. It should be `Q3: S = 2 + 4j`

Q1. RMS. Given Figure 1, answer the following questions.

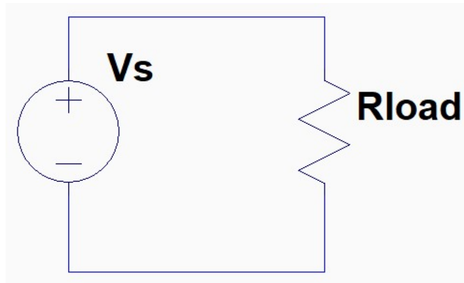

Figure 1

Line 1. For Vs is a DC voltage source of 50 V, find power dissipated on Rload for Rload = 20 ohm.
Line 2. For Vs is a DC voltage source of 70.711 V, find power dissipated on Rload for Rload = 20 ohm.
Line 3. For Vs is a sinusoidal voltage source of 100 Vpp, find peak voltage, rms voltage, and power dissipated on Rload for Rload = 20 ohm.
Line 4. For Vs is a sinusoidal voltage source of 141.422 Vpp, find peak voltage, rms voltage, and dissipated on Rload for Rload = 20 ohm.
Line 5. For Vs is a sinusoidal voltage source of 150 Vpp, find an equivalent DC voltage source that can replace Vs and still have the same power dissipated on Rload. What DC voltage of the replacement source should be?

Write your answers in the following format. (Edit the *italic gray*, but keep the **bold black**.)

1	**Vs 50 V, P =** *0* **W.**
2	**Vs 70.711 V, P =** *0* **W.**
3	**Vs 100.000 Vpp, Vp =** *0* **V, Vrms =** *0* **V, P =** *0* **W.**
4	**Vs 141.422 Vpp, Vp =** *0* **V, Vrms =** *0* **V, P =** *0* **W.**
5	**Vdc =** *0* **V.**

Grading: eeeee
Report: Hint

$V_s = 75$

Q2. Inverse Problem. Given Figure 2, an inductive load *Z*, which is a series of *R1* and *L1* of the given circuit, has its terminal voltage, *Va*, measured to be 220 Vrms (at 50 Hz with phase 0 rad) and the current flowing into its positive terminal, *iab*, measured to be 0.4 Arms with phase -1.41372 rad. Answer the following questions.

$V_{rms} = \frac{V_p}{\sqrt{2}}$

$V_p = V_{rms}\sqrt{2}$

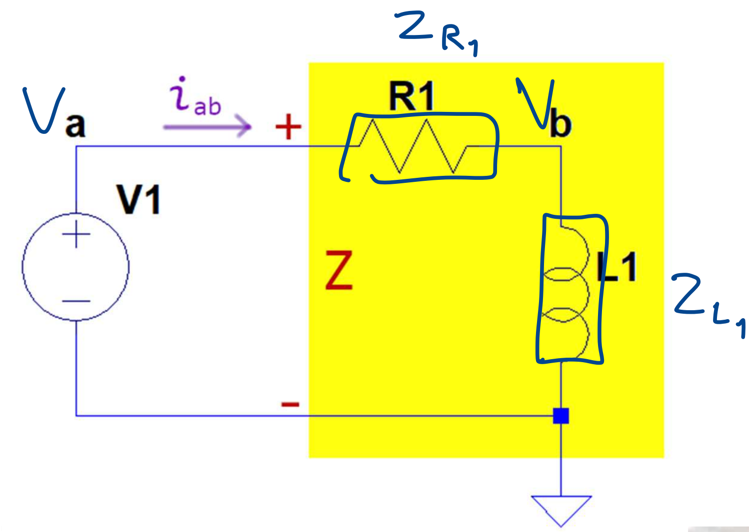

Figure 2

$-V_1 + Z = 0$

Line 1. Deduce nodal voltage at node a, *Va*, in a phasor form.
Line 2. Deduce current *iab*, in a phasor form.
Line 3. Deduce impedance of *Z*.
Line 4. Deduce resistance of *R1*.
Line 5. Deduce inductance of *L1*.

```
Hint!
1. Recall what rms is.
2. Impedance property: V = I Z.
3. Z is a series of R1 (real part) and L1 (imaginary part).
4. Recall that impedance of L = j w L, where w is an angular frequency.
5. This is actually an easy question.
```

Write your answers in the following format. (Edit the *italic gray*, but keep the **bold black**.)

```
1  Va: magnitude = 0 Vp, phase = 0 rad.
2  iab: magnitude = 0 Ap, phase = 0 rad.
3  Q2.3: Z = 0 + 0j
4  R1 = 0 ohm.
5  L1 = 0 H.
```

543.228

$X_L = j\omega L$

$\frac{543.228}{2\pi(50)}$

Grading: eePee
Report: Hint

$Z_{L_1} = j\omega L$

$\omega = 314.1593$

$Z = 86.037 + 543.228j$

$R_1 = 86.037$

$L_1 = 543.228$

Q3. Power Factor. Answer the following questions. CIVIL

Line 1. Given a resistor of 100 ohm, what is its power factor? Is it leading or lagging?
Line 2. Given a capacitor of 20 nF, what is its power factor? Is it leading or lagging?
Line 3. Given an inductor of 400 mH, what is its power factor? Is it leading or lagging?
Line 4. Given an impedance of 100 + 20j ohm, what is its power factor? Is it leading or lagging?
Line 5. Given a load having an average power of 100W at operating voltage 500 Vrms and power factor of 0.8 lagging, what is its impedance?
Line 6. Given a load having an average power of 100W at operating voltage 500 Vrms and power factor of 0.9 leading, what is its impedance?

Hint!
1. Recall that leading means "I is leading V" ($\theta_V - \theta_I < 0$) and lagging means "I is lagging V" ($\theta_V - \theta_I > 0$).
2. Power $P = V \cdot I \cdot \cos(\theta) = V \cdot I \cdot pf$, where $\theta = \theta_V - \theta_I$.
3. $\boldsymbol{Z} = \boldsymbol{V}/\boldsymbol{I} = |V|/|I| \angle(\theta_V - \theta_I)$.

Write your answers in the following format. (Edit the *italic gray*, but keep the **bold black**.)

```
1  R 100Ohm, pf = 0.000
2  C 20nF, pf = 0.000 leading/lagging
3  L 400mH, pf = 0.000 leading/lagging
4  Z 100+20j, pf = 0.000 leading/lagging
5  Q3.5: pf 0.8 lagging, Z = 0 + 0j
6  Q3.6: pf 0.9 leading, Z = 0 + 0j
```

Grading: eeeePP
Report: Hint

$$P_{avg} = I_{rms} \cdot V_{rms} \underbrace{\cos(\theta_V - \theta_i)}_{}$$ 0.8

$$\frac{100}{(500)(0.8)} = I_{rms} = 0.25$$

$$Z = \frac{V}{I}$$

$$\frac{100}{(500)(0.9)} = I_{rms}$$

Q4. Complex Power. Answer the following questions.

Line 1. Given a complex power of 400 + 300j VA, deduce the average power and power factor.
Line 2. Given a complex power of 140 – 70j VA, deduce the average power and power factor.
Line 3. Given a complex power of 700 VA, deduce the average power and power factor.
Line 4. Given a load operating at 220 Vrms and consuming an average power of 200W with a lagging power factor of 0.98, deduce the complex power on the load.
Line 5. Given information as line 4, deduce an impedance of the load.
Line 6. Given a load operating at 120 Vrms and consuming an average power of 32W with a leading power factor of 0.95, deduce the complex power on the load.
Line 7. Given information as line 6, deduce an impedance of the load.

Write your answers in the following format. (Edit the *italic gray*, but keep the **bold black**.)

```
1  S 400+300j, P = 0 W, PF = 0 lagging/leading
2  S 140-70j, P = 0 W, PF = 0 lagging/leading
3  S 700, P = 0 W, PF = 0
4  Q4.4: Load 200W at 220 Vrms pf 0.98 lagging, S = 0 + 0j
5  Q4.5: Load 200W at 220 Vrms pf 0.98 lagging, Z = 0 + 0j
6  Q4.6: Load 32W at 120 Vrms pf 0.95 leading, S = 0 + 0j
7  Q4.7: Load 32W at 120 Vrms pf 0.95 leading, Z = 0 + 0j
```

Grading: eeePPPP
Report: Hint

P

$Q = \tan\theta \, P$

$I = \frac{P}{V} = \frac{200}{220 \cdot 0{,}98}$ $\quad I = 0{,}9276438$

$Z = \frac{V}{I}$ $\quad I = 0{,}2807018$

Q5. Power Factor and Power Loss. Given Figure 5, answer the following questions.

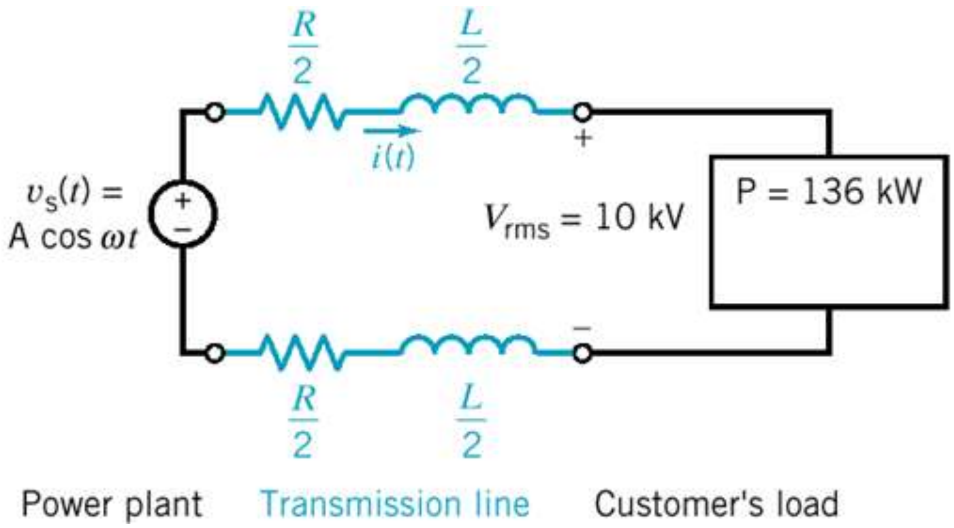

Figure 5

Line 1. Deduce line current i (in A_{rms}) and power dissipated on line (R = 10 ohm), when the load having power factor of 0.8 lagging.
Line 2. Deduce line current i (in A_{rms}) and power dissipated on line (R = 10 ohm), when the load having power factor of 0.95 lagging.

```
Hint!
1. Power P = V·I·cos(θ) = V·I·pf, where θ = θV - θI.
3. Power on transmission line PLine = Irms^2 · R.
```

Write your answers in the following format. (Edit the *italic gray*, but keep the **bold black**.)

```
1  pf 0.8 lagging, i = 0 Arms, P = 0 W.
2  pf 0.95 lagging, i = 0 Arms, P = 0 W.
```

Grading: ee
Report: Hint

Fun fact! Recall that the load where the work is consumes the same amount of power, but the less power factor is, the more power electrical supplier has to supply. The extra is just wasted on the transmission line.

THE END

$pf = 0.8$

$P = VI\,pf$

$$\frac{P}{V\,pf} = I$$

$$\frac{136 \times 10^3}{(10 \times 10^3)(0.8)} = I$$

$P_{line} =$

$I_{rms} = 17$

$P_{line} = 1445$

$I_{rms} = 14.31579$

$P_{line} = 1024.709$

$X_L = j\omega L$

$$L = \frac{X_L}{j\omega}$$