

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: 1ca2022 (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 x (Over tolerance) |
| vx = -12.4 V; ix = 18.5 e-3 A | BAD FORMAT! x |
| vx = -12.4V; ix = 18.5mA | BAD FORMAT! x |
| vx =-12.4V; ix =18.5mA | BAD FORMAT! x |
| vx =-12.4V ix =18.5mA | BAD FORMAT! x |
| vx =-12.4V. ix =18.5mA | BAD FORMAT! x |

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 testargs: # testargs: 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 /**

$v_2(t) = 8 - 6 \cdot \exp(-50 \cdot t)$
 $v_2(t) = - 6 \cdot \exp(-50 \cdot t) + 8$
 $v_2(t) = 6 \cdot \exp(-50 \cdot t) + 8$
 $v_2(t) = 8 - 6 \exp(-t/0.02)$

GOOD FORMAT /
 GOOD FORMAT /
 GOOD FORMAT × but wrong!
 BAD! × syntax error

$v(t) = 8 - 6 \cdot \exp(-t/0.02)$
 $v_2(t) : 8 - 6 \cdot \exp(-t/0.02)$
 $v_2(t) = 8 - 6 \cdot e^{(-t/0.02)}$
 $v_2(t) = 8 - 6 \cdot \exp(-\text{time}/0.02)$

BAD FORMAT! × QID not found
 BAD FORMAT! × no QID specified
 BAD! × unsupported operand
 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 “ $f(x) = 0.1 \cdot x$ ” and student’s answer of “ $f(x) = 0.101 \cdot x$ ” 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.

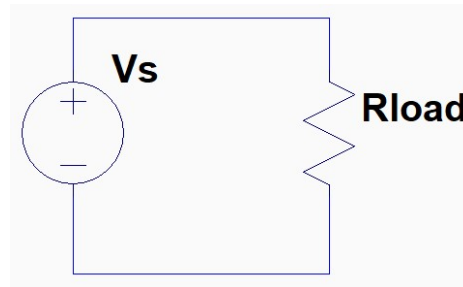


Figure 1

Line 1. For V_s is a DC voltage source of 50 V, find power dissipated on R_{load} for $R_{load} = 20 \text{ ohm}$.

Line 2. For V_s is a DC voltage source of 70.711 V, find power dissipated on R_{load} for $R_{load} = 20 \text{ ohm}$.

Line 3. For V_s is a sinusoidal voltage source of 100 Vpp, find peak voltage, rms voltage, and power dissipated on R_{load} for $R_{load} = 20 \text{ ohm}$.

Line 4. For V_s is a sinusoidal voltage source of 141.422 Vpp, find peak voltage, rms voltage, and power dissipated on R_{load} for $R_{load} = 20 \text{ ohm}$.

Line 5. For V_s is a sinusoidal voltage source of 150 Vpp, find an equivalent DC voltage source that can replace V_s and still have the same power dissipated on R_{load} . 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 | V_s 50 V, $P = 0 \text{ W}$. |
| 2 | V_s 70.711 V, $P = 0 \text{ W}$. |
| 3 | V_s 100.000 Vpp, $V_p = 0 \text{ V}$, $V_{rms} = 0 \text{ V}$, $P = 0 \text{ W}$. |
| 4 | V_s 141.422 Vpp, $V_p = 0 \text{ V}$, $V_{rms} = 0 \text{ V}$, $P = 0 \text{ W}$. |
| 5 | $V_{dc} = 0 \text{ V}$. |

Grading: eeeee

Report: Hint

Q.1

$$1. P = \frac{V^2}{R} ; V = 50V, R = 20 \Omega$$

$$P = \frac{50^2}{20} = 125 \text{ Watt}$$

$$2. P = \frac{V^2}{R} ; V = 70.711, R = 20$$

$$= \frac{(70.711)^2}{20} = 250.0023 \text{ Watt}$$

$$3. V_S = 100.000 V_{pp}$$

$$V_p = \frac{V_{pp}}{2} = 50.000 V_p$$

$$V_{rms} = \frac{V_p}{\sqrt{2}} = \frac{50}{\sqrt{2}} = 35.35534 V_{rms}$$

$$P = \frac{V_{rms}^2}{R} = 62.5 \text{ W}$$

$$4. \quad V_p = \frac{141.422}{2} = 70.711 \quad V_p$$

$$V_{rms} = \frac{70.711}{\sqrt{2}} = 50.00029 \quad V_{rms}$$

$$P = \frac{V_{rms}^2}{R} = 125.0011 \text{ Watt}$$

$$5. \quad \text{find } V_{dc} \quad V_{dc} = V_{rms}$$

$$V_{pp} = 150$$

$$V_p = \frac{150}{2}$$

$$V_{rms} = \frac{V_p}{\sqrt{2}} = 53.03307 \quad V$$

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, V_a , measured to be 220 Vrms (at 50 Hz with phase 0 rad) and the current flowing into its positive terminal, i_{ab} , measured to be 0.4 Arms with phase -1.41372 rad. Answer the following questions.

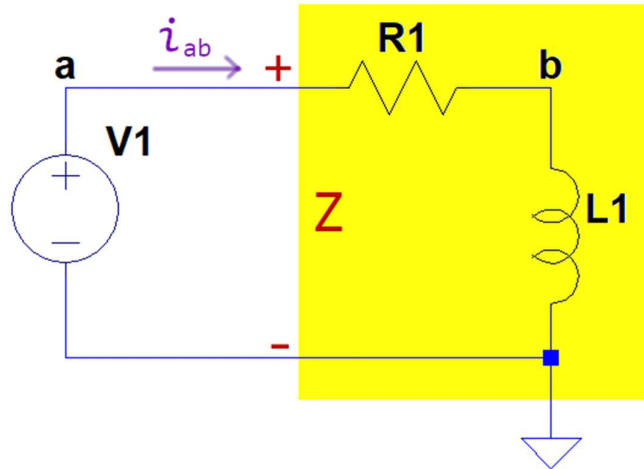


Figure 2

Line 1. Deduce nodal voltage at node a, V_a , in a phasor form.

Line 2. Deduce current i_{ab} , 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 $L = j \omega L$, where ω 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. |

Grading: eePee

Report: Hint

Q2.

1. $V_a = 220 \text{ Vrms}$

magnitude = $V_p = (220)(\sqrt{2})$, phase = 0

2. $i_{ab} = 0.4 \text{ Arms}$

magnitude = $i_p = (0.4)(\sqrt{2})$, phase = -1.41372

3. find Z

$$V = IZ$$

$$Z = \frac{V}{I} = \frac{220}{0.4 \angle -1.41372}$$

$$= \underbrace{86.0372}_{Z_R} + \underbrace{543.2289i}_{Z_L}$$

4. $Z_R = R = 86.0372 \Omega$

$$Z_L = j\omega L$$

$$L = \frac{Z_L}{j\omega} = \frac{543.2289}{j\omega} ; \omega = 2\pi(50)$$

5. $\text{Mod}(L) = 1.7291 \text{ H}$

Q3. Power Factor. Answer the following questions.

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. $Z = V/I = |V|/|I| \angle(\theta_V - \theta_I)$.

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 <i>Leading/lagging</i> |
| 3 | L 400mH , pf = 0.000 <i>Leading/lagging</i> |
| 4 | Z 100+20j , pf = 0.000 <i>Leading/lagging</i> |
| 5 | Q3.5: pf 0.8 lagging , Z = $\theta + \theta j$ |
| 6 | Q3.6: pf 0.9 leading , Z = $\theta + \theta j$ |

Grading: eeeePP

Report: Hint

$$1. R = 1000 \Omega \quad pf = 1$$

R & phase V, I same

$$2. C = 20 \text{ nF}, \quad pf = 0.000 \quad \text{leading}$$

$$C = I \sin V$$

$$3. L = 100 \text{ mH}, \quad pf = 0.000 \quad \text{lagging}$$

$$L = V \sin I$$

$$4. Z = 100 + 20j \quad \text{find power factor (pf)}$$

$$pf = \cos(\theta_v - \theta_i) = \frac{R}{Z}$$

$$\cos(\theta_v - \theta_i) = \frac{100}{100 + 20j} = 0.9805807$$

$$5. pf = 0.8 \text{ lagging } (\theta_v - \theta_i > 0)$$

$$P = 100 \text{ W}$$

$$V_{rms} = 500$$

$$pf = \cos(\theta_v - \theta_i) = 0.8$$

$$P = V_{rms} I_{rms} pf$$

$$I = 0.25$$

$$Z = \frac{V}{I} \angle \theta_v - \theta_i$$

$$Z = \frac{500}{0.25} \angle \cos(0.8)$$

$$Z = \dots$$

$$\text{p.f.} = 0.9 \text{ leading } (\phi_v - \phi_i < 0)$$

$$P = VI_p f$$

$$I = 0.2222$$

$$Z = \frac{500}{I} \angle \cos(0.9)$$

$$Z = 2025 + 780.752i$$

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

Grading: eeePPPP

Report: Hint

$$S = \underbrace{P}_{\text{Real power}} + j \underbrace{Q}_{\text{Reactive power}}$$

$$1. S = 400 + 300j$$

$$P = 400 \text{ Watt}$$

$$pf = \cos(\theta_v - \theta_i) = \frac{P}{S} = \frac{400}{400 + 300j}$$

$$\text{Mod} = 0.8 \text{ lagging}$$

$$2. S = 140 - 70j$$

$$P = 140$$

$$pf = \frac{P}{S} = \frac{140}{140 - 70j} = 0.8944272 \text{ lagging}$$

$$3. S = 700$$

$$P = 700$$

$$pf = \frac{P}{S} = \frac{700}{700} = 1$$

$$4. P = 200 \quad \text{find } S \quad pf = \frac{P}{S}$$

$$V_{rms} = 220$$

$$pf = 0.98$$

$$S = \frac{P}{pf} = \frac{200}{0.98} \angle \cos(0.98)$$

$$= 200 + 40.6117j$$

$$Z = ?$$

$$\textcircled{5} S = \frac{V^2}{Z} \quad ; \quad Z = \frac{V_{rms}^2}{S} = 232.4168 - 47.1912i$$

$$\textcircled{6} P = 32$$

$$V_{rms} = 120$$

$$\text{pf} = 0.95$$

$$\text{pf} = \frac{P}{S} \quad \text{(leading)}$$

$$S = \frac{P}{\text{pf}} = \frac{32}{0.95} \quad \downarrow \quad \angle -\cos(0.95)$$

$$S = 32 - 10.51789i$$

$$\textcircled{7} Z = \frac{V_{rms}^2}{S} = \frac{120^2}{S} = 406.725 + 133.4268i$$

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

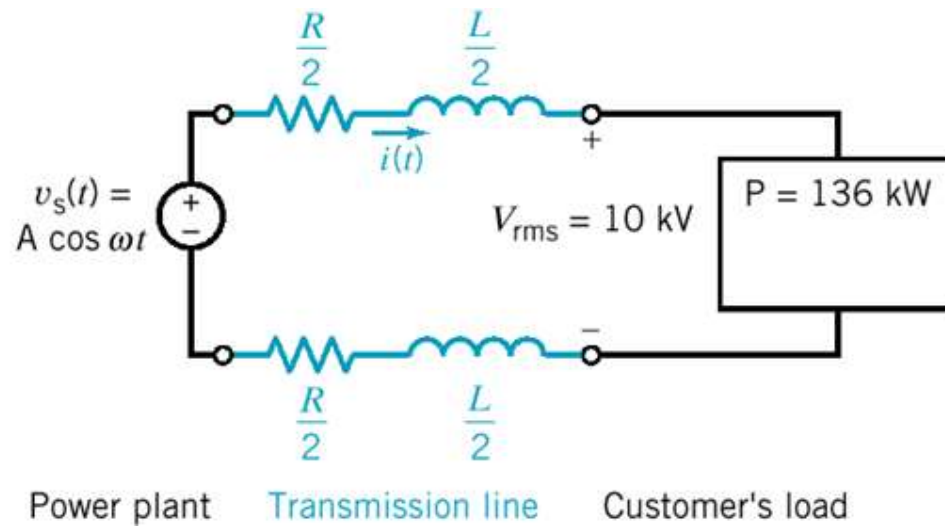


Figure 5

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 $P = V \cdot I \cdot \cos(\theta) = V \cdot I \cdot pf$, where $\theta = \theta_v - \theta_i$.

3. Power on transmission line $P_{Line} = I_{rms}^2 \cdot R$.

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

| | |
|---|---|
| 1 | pf 0.8 lagging, $i = \theta$ Arms, $P = \theta$ W. |
| 2 | pf 0.95 lagging, $i = \theta$ Arms, $P = \theta$ 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

$$1. V_{rms} = 10,000 \quad P = 136,000$$

$$pf = 0.8$$

$$(\theta_v - \theta_i) = \arccos(0.8)$$

$$P = V_{rms} I_{rms} pf$$

$$I_{rms} = \frac{P}{V_{rms} pf} = 17$$

$$P_{line} = (17^2)(10) \quad \swarrow R_{line} = 2890$$

$$pf = 0.95$$

$$2. I_{rms} = \frac{P}{V_{rms} pf} = \frac{136,000}{(10,000)(0.95)} = 14.37579$$

$$P_{line} = (14.37579)^2 (10) = 2049.418$$