

4/20/2005

University of Portland
School of Engineering

EE 301-Electromagnetic Fields-3 cr. hrs.
Spring 2005

Midterm Exam # 2
Sinusoidal Steady-State Waves on Transmission Lines
(Prepared by Professor A. S. Inan)

(Monday, April 11, 2005)
(Closed Book Exam; 1 Formula Sheet Allowed)
(Total Time: 55 mins.)

Name: SOLUTIONS! ☺

Signature: *[Handwritten Signature]* ☺

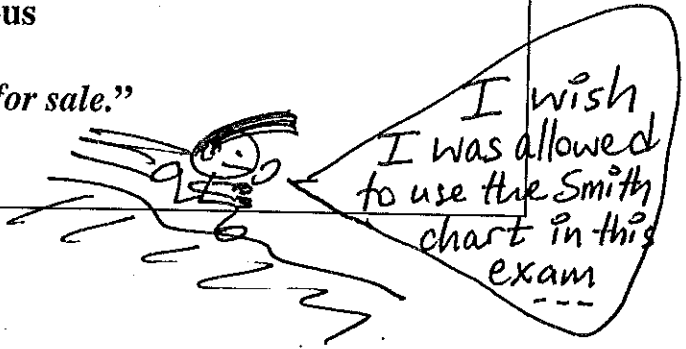
Go get it!
Hurry up!

"Honesty is the best policy."
Aesop (~ 620B.C. -?)

"An honest mind possesses a kingdom."
Lucius Annaeus Seneca (4B.C.-65A.D.)

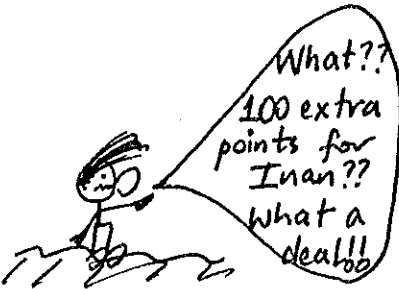
"Honest people are the true winners of the universe."
Anonymous

"Honesty is not for sale."
A. Inan

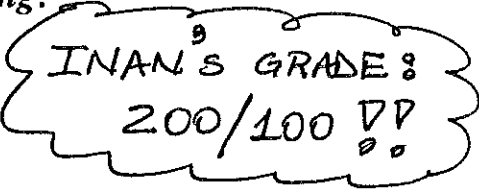


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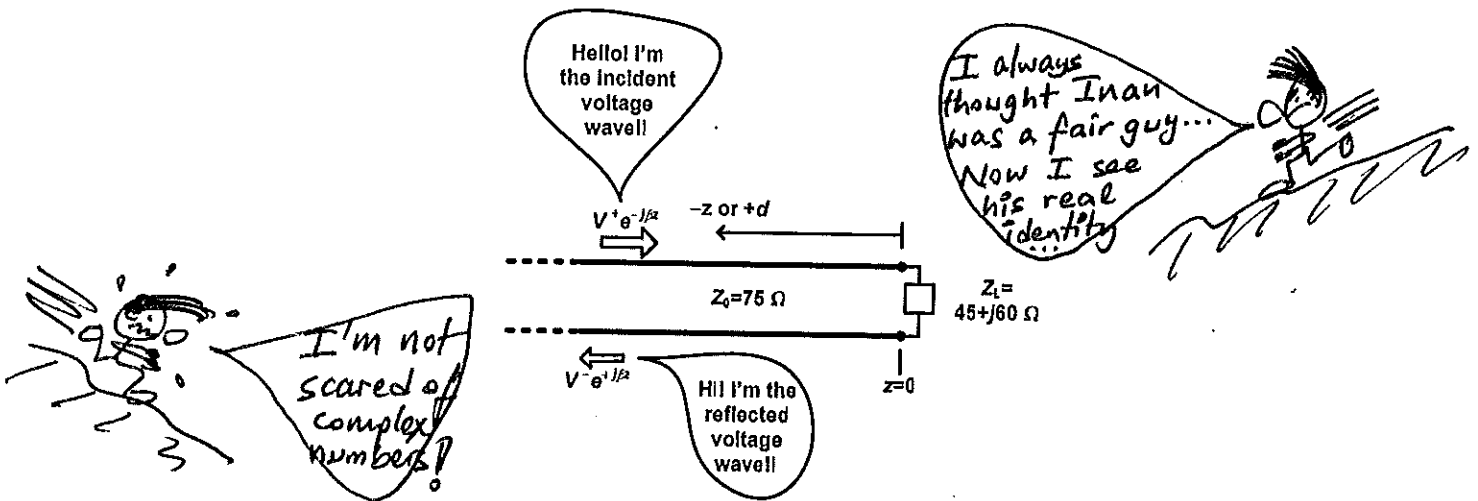
This table will be used by Inan for grading!



Problem #	Points gained
#1	40
#2	30
#3	30
Total	100 + 100 extra credit to Inan for his solutions!



(1) (15 mins., Total: 40 points) A lossless transmission line terminated with a complex impedance. A 75Ω transmission line is terminated with an inductive load impedance given by $Z_L = 45 + j60\Omega$, as shown.



(a) (10 points) Calculate the load reflection coefficient, Γ_L . (Provide your answer in polar form.) Show your work!

$$\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{45 + j60 - 75}{45 + j60 + 75}$$

$$= \frac{-30 + j60}{120 + j60} = \frac{-1 + j2}{4 + j2}$$

$$= \frac{\sqrt{5} e^{j \tan^{-1}(-2) + j\pi}}{2\sqrt{5} e^{j \tan^{-1}(0.5)}} = \boxed{\frac{1}{2} e^{j\pi/2}}$$



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(b) (10 points) What is the value of the standing wave ratio, S , on the line?

Extra points for special people like himself and not for others...

And all this lecturing about honesty...

$$S = \frac{1 + |\Gamma_L|}{1 - |\Gamma_L|} = \frac{1 + 0.5}{1 - 0.5} = \boxed{3}$$



Don't hide behind the "Honesty is not for sale" cliché I may I now know your real face!

Your double standard conflicts with the root of the meaning of the word honesty...

(c) (10 points) Find the percentage time-average incident power that is absorbed by the load.

% time-average incident power delivered to the load can be calculated as

$$(1 - |\Gamma_L|^2) \times 100 = (1 - (0.5)^2) \times 100 = \boxed{75\%}$$

(d) (10 points) Find the V_{\max} and V_{\min} positions nearest to the load. Provide your answers as electrical lengths.

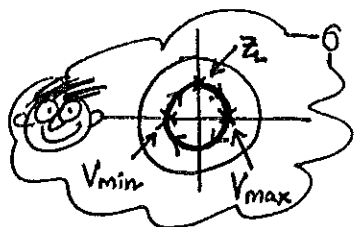
$$\frac{z\pi}{\lambda}$$

$$\phi_L = \frac{\pi}{2}$$

$$\phi_L + 2\beta z_{\max} = 0 \rightarrow z_{\max}/\lambda = \boxed{-0.125}$$

$$\phi_L + 2\beta z_{\min} = -\pi \rightarrow z_{\min}/\lambda = \boxed{-0.375}$$

Note that as expected, $|z_{\max} - z_{\min}|/\lambda = 0.25$



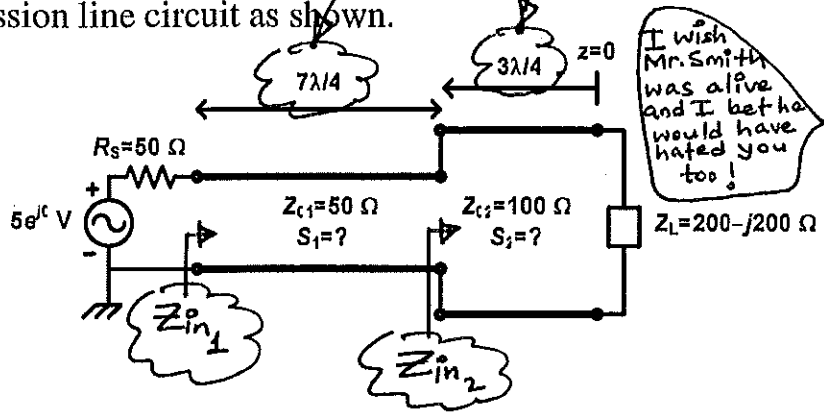
And it is unfair not to let us use the Smith chart!!

You use it whenever you want to, don't you?

I hate you for not allowing us to use the Smith chart!

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(2) (15 mins., Total: 30 points) Two cascaded transmission lines. Consider the transmission line circuit as shown.



I wish Mr. Smith was alive and I bet he would have hated you too!

I'm here and I agree with you 100%!!

(a) (15 points) Find the standing wave ratio on each line. Show your work!

$$\Gamma_L = \frac{Z_L - Z_{o2}}{Z_L + Z_{o2}} = \frac{200 - j200 - 100}{200 - j200 + 100} = \frac{100 - j200}{300 - j200}$$

$$= \frac{\sqrt{5} e^{j \tan^{-1}(-2)}}{\sqrt{13} e^{j \tan^{-1}(-2/3)}} \approx 0.62 e^{-j29.7^\circ}$$

$$\therefore S_2 = \frac{1 + |\Gamma_2(z)|}{1 - |\Gamma_2(z)|} = \frac{1 + |\Gamma_L|}{1 - |\Gamma_L|} \approx \frac{1 + 0.62}{1 - 0.62} \approx \boxed{4.27}$$

$$Z_{in2} = \frac{Z_{o2}^2}{Z_L} = \frac{(100)^2}{200 - j200} = \frac{50}{1 - j} = 25 + j25 \Omega$$

$$|\Gamma_1(z)| = \left| \frac{25 + j25 - 50}{25 + j25 + 50} \right| = \left| \frac{-25 + j25}{75 + j25} \right| = \left| \frac{-1 + j}{3 + j} \right| = \frac{\sqrt{2}}{\sqrt{10}}$$

$$= \frac{1}{\sqrt{5}} \approx 0.447$$

$$\therefore S_1 = \frac{1 + |\Gamma_1(z)|}{1 - |\Gamma_1(z)|} \approx \frac{1 + 0.447}{1 - 0.447} \approx \boxed{2.62}$$

Who was that? Mr. Smith? Mr. Smith, are you here? Is that you??

Yes! Keep quiet!!!

I can't believe my ears!!!

He is here!!!

Inan should know that I'm talking with Mr. Smith!

He may think that I'm getting help from him, I'm cheating!

"Honesty is not for sale" versus 100 extra points for Inan!!

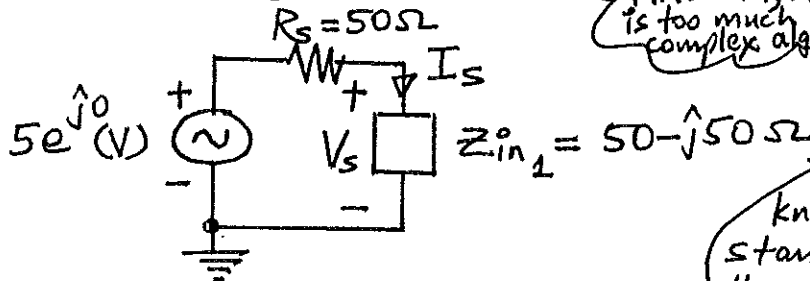
What a deal!! * @ * % #

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(b) (15 points) Find the time-average power delivered to the load impedance.

$$Z_{in_1}^{\circ} = \frac{Z_{o1}^2}{Z_{in_2}} = \frac{(50)^2}{25 + j25} = \frac{100}{(1+j)} \cdot \frac{(1-j)}{(1-j)}$$

$$= 50 - j50 \Omega$$



Please help me Mr. Smith, there is too much complex algebra...

I never knew that double standard falls in the category of honesty... This must be Inan's new definition of honesty...

$$V_s = \frac{50 - j50}{50 + 50 - j50} (5) = \frac{5(1-j)}{(2-j)}$$

$$= (1-j)(2+j) = 3 - j \approx 3.16 e^{-j18.4^\circ} (V)$$

$$I_s = \frac{V_s}{Z_{in_1}} = \frac{3-j}{50-j50} = \frac{(3-j)(1+j)}{50(1-j)(1+j)}$$

$$= \frac{4+j2}{100} = \frac{2+j}{50} \approx 44.7 e^{j26.6^\circ} (mA)$$

$$\therefore P_{Z_{in_1}} = P_L = \frac{1}{2} |V_s| |I_s| \cos(\angle V_s - \angle I_s)$$

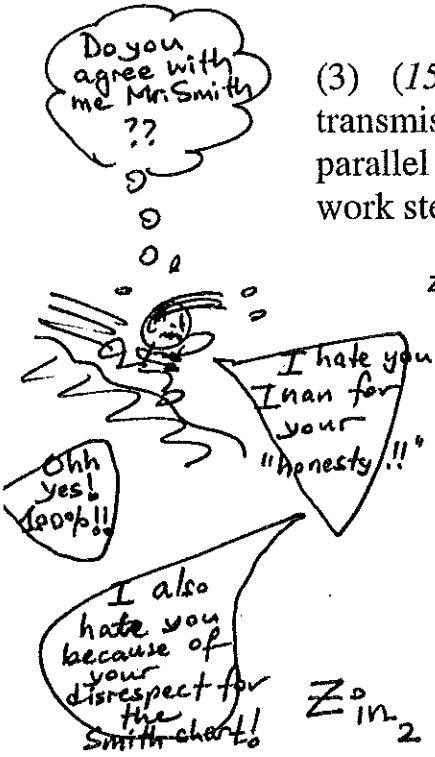
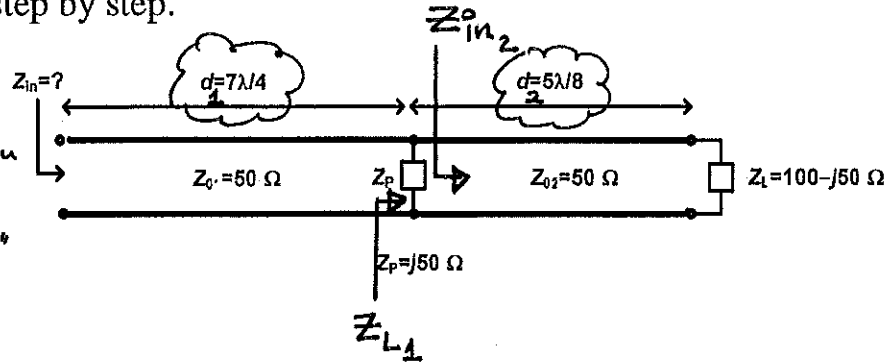
$$\approx \frac{1}{2} (3.16)(44.7) \cos(-18.4^\circ - 26.6^\circ) \approx \boxed{50 \text{ mW}}$$

* @ *
* @ *

Thanks Inan for teaching one more thing about honesty before I go into the real world...

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(3) (15 mins., 30 points) **Input impedance.** Consider the transmission line circuit as shown where Z_p impedance represents a parallel lumped element. Find the input impedance Z_{in} . Show your work step by step.



$$Z_{in_2} = Z_{02} \frac{Z_L + j Z_{02} \tan(\beta d_2)}{Z_{02} + j Z_L \tan(\beta d_2)} = (50) \frac{(100 - j50) + j50 \tan\left(\frac{2\pi}{\lambda} \cdot \frac{5\lambda}{8}\right)}{50 + j(100 - j50) \tan\left(\frac{2\pi}{\lambda} \cdot \frac{5\lambda}{8}\right)}$$

$$= (50) \frac{100}{100 + j100} = \frac{50(1 - j)}{(1 + j)(1 - j)} = 25 - j25 \Omega$$

$$Z_{L1} = \frac{Z_p \cdot Z_{in_2}}{Z_p + Z_{in_2}} = \frac{(j50)(25 - j25)}{j50 + 25 - j25}$$

$$= \frac{j50(1 - j)}{(1 + j)} \cdot \frac{(1 - j)}{(1 - j)} = \frac{(j50)(-j2)}{2} = 50 \Omega \checkmark$$

∴ Regardless of the length of d_1 , $Z_{in} = 50 \Omega$

