Fields and Waves I

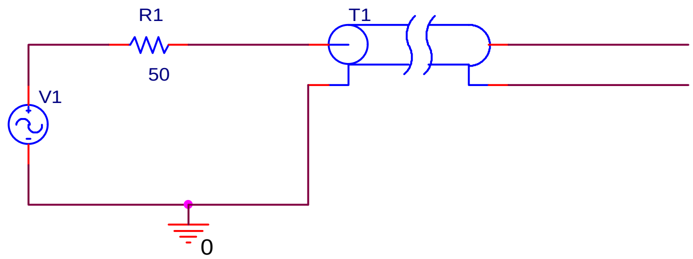
Name ______________ ECSE-2100 Spring 2000 Section _______

Homework 8
Comprehensive Review of Semester
Practice Final Exam

Note: The Final Will Have More Questions Than This Assignment

Part One: Short Questions

1. Transmission Lines



A 100 meter long air insulated lossless transmission line has an open circuit at its load end. At low frequencies (near $\omega = 0$), does the line look like an inductor, a capacitor or a resistor? (Circle the correct answer.) Which of the following frequencies are low? (Again, circle the correct answers.)

f = 1 kHz. f = 100 kHz f = 1 MHz f = 100MHz f = 1 GHz

2. Capacitance

A parallel plate capacitor can be constructed using any of the following combinations of materials. Which will result in the largest capacitance?

a. Teflon sheet ($\varepsilon_r = 2.10$), 1 meter by 1 meter by 3 mm, with aluminum foil on each side.

b. Fused quartz sheet ($\varepsilon_r = 3.8$), 0.3 meter by 0.5 meter by 1 mm, with aluminum foil on each side.

c. Distilled water ($\varepsilon_r = 80$), 0.2 meter by 0.3 meter by 3 mm, with aluminum foil on each side. (The top piece of foil is held up by surface tension.)

3. Good Conductor or Good Dielectric?

Circle the frequencies at which sea water is a good conductor. Cross out the frequencies at which sea water is a good dielectric. $\varepsilon_r = 72$, $\sigma = 4$ S/m.

1Hz 10Hz 100Hz 1kHz 10kHz 100kHz 1MHz 10MHz
100MHz 1GHz 10GHz 100GHz 1THz 10THz 100THz

4. Electric Fields

The potential structure of a coaxial cable is analyzed using the finite difference method we applied using Excel Spreadsheets. One big problem with this method is that is it difficult to properly model circular or cylindrical objects, like coaxial cables. However, if one uses a lot of very small cells, errors can be made arbitrarily small. The analysis of such a structure using a 21x21 matrix gives the results shown below. Shown are the values of the voltages in each cell. The potentials in each cell are determined to several significant digits, but only two digits are shown due to the very small size of the cells. Thus, most of the numbers displayed are not accurate. However, there is at least one cell that has the correct relationship to its neighbors. Can you find such a cell? If so, circle it and show that it is properly related to its neighbors.

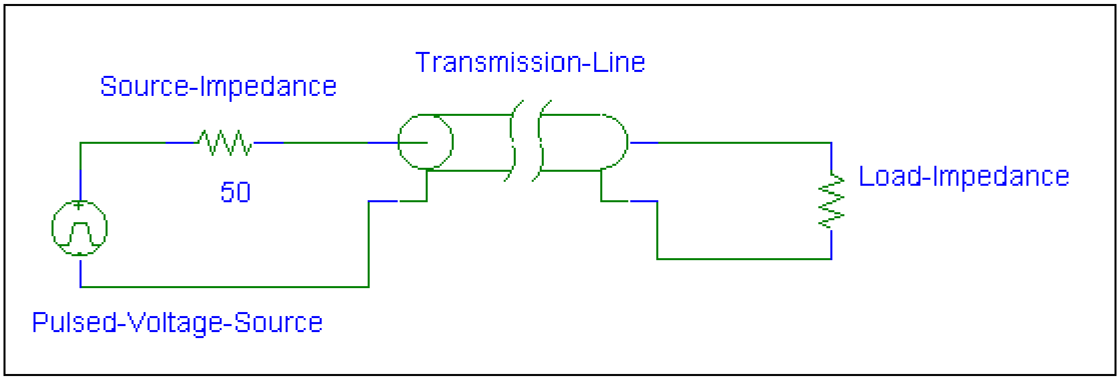
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0.4	0.6	0.6	0.7	0.6	0.6	0.4	0	0	0	0	0	0	0
0	0	0	0	0.3	0.5	0.7	1	1.2	1.3	1.4	1.3	1.2	1	0.7	0.5	0.3	0	0	0	0
0	0	0	0.4	0.7	1.1	1.4	1.7	2	2.1	2.2	2.1	2	1.7	1.4	1.1	0.8	0.4	0.2	0	0
0	0	0.3	0.7	1.2	1.6	2	2.4	2.8	3	3.1	3	2.8	2.5	2.1	1.6	1.2	0.8	0.4	0	0
0	0	0.5	1.1	1.6	2.2	2.7	3.3	3.7	4	4.2	4	3.7	3.3	2.7	2.2	1.6	1.1	0.6	0	0
0	0	0.7	1.4	2	2.7	3.4	4.2	4.8	5.3	5.4	5.3	4.8	4.2	3.5	2.7	2.1	1.4	0.7	0	0
0	0.4	1	1.7	2.4	3.3	4.2	5.1	6.1	6.9	7	6.9	6.1	5.1	4.2	3.3	2.5	1.7	1	0.4	0
0	0.6	1.2	2	2.8	3.7	4.8	6.1	7.5	9	9	9	7.5	6.1	4.8	3.7	2.8	2	1.2	0.6	0
0	0.6	1.3	2.1	3	4	5.3	6.8	9	9	9	9	9	6.9	5.3	4	3	2.1	1.3	0.6	0
0	0.7	1.4	2.2	3.1	4.2	5.4	7	9	9	9	9	9	7	5.4	4.2	3.1	2.2	1.4	0.7	0
0	0.6	1.3	2.1	3	4	5.3	6.8	9	9	9	9	9	6.9	5.3	4	3	2.1	1.3	0.6	0
0	0.6	1.2	2	2.8	3.7	4.8	6.1	7.5	9	9	9	7.5	6.1	4.8	3.7	2.8	2	1.2	0.6	0
0	0.4	1	1.7	2.4	3.3	4.2	5.1	6.1	6.9	7	6.9	6.1	5.1	4.2	3.3	2.4	1.7	1	0.4	0
0	0	0.7	1.4	2	2.7	3.4	4.2	4.8	5.3	5.4	5.3	4.8	4.2	3.4	2.7	2	1.4	0.7	0	0
0	0	0.5	1.1	1.6	2.2	2.7	3.3	3.7	4	4.2	4	3.7	3.3	2.7	2.2	1.6	1.1	0.5	0	0
0	0	0.3	0.7	1.2	1.6	2	2.4	2.8	3	3.1	3	2.8	2.4	2	1.6	1.2	0.7	0.3	0	0
0	0	0	0.4	0.7	1.1	1.4	1.7	2	2.1	2.2	2.1	2	1.7	1.4	1.1	0.7	0.4	0	0	0
0	0	0	0	0.3	0.5	0.7	1	1.2	1.3	1.4	1.3	1.2	1	0.7	0.5	0.3	0	0	0	0
0	0	0	0	0	0	0	0.4	0.6	0.6	0.7	0.6	0.6	0.4	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

5. Electromagnetic Waves (Circle the correct answers.)

a. The distance between two adjacent maxima in a voltage standing wave pattern is ($\lambda/4$, $\lambda/2$, λ, 2λ).

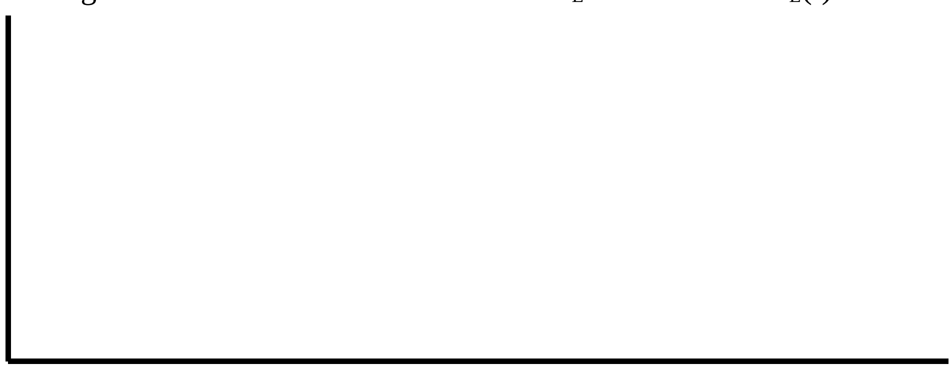
b. A uniform plane wave is incident obliquely at 15^o on the surface of a large piece of glass ($\varepsilon_r = 4$). The angle of incidence is (equal to, greater than, less than) the angle of reflection. The angle of transmission is (equal to, greater than, less than) the angle of incidence.

6. Transmission Lines



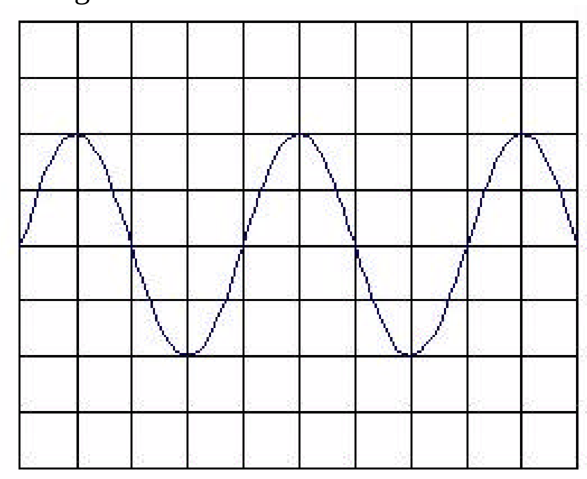
A 400 meter long transmission line with $Z_o = 50\Omega$ and $v_{ph} = 2 \times 10^8$ m/s connected a pulsed voltage source to a resistive load. A single pulse (magnitude = V_o, duration = 1µs) is emitted from the source. The source impedance is 50Ω. If the load resistance R_L = 10MΩ, what voltage is observed at the load? Plot $V_L(t)$.

What voltage function is observed at the load if R_L = 50Ω? Plot $V_L(t)$.



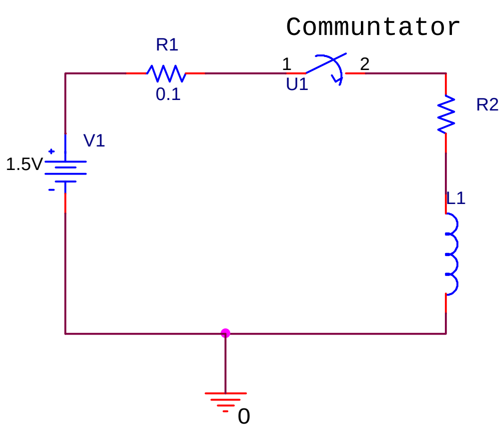
7. Faraday's Law

Assume that you have one of the coils made for the Beakman's motor project. You place it in a structure that causes it to rotate with a constant angular frequency ω. Assume also that this rotating coil is placed in a uniform magnetic field whose direction aligns with the coil and anti-aligns with the coil once every revolution. That is, the magnetic field **B** is exactly perpendicular to the axis of the coil. A 'scope connected to the coil shows the waveform below. The 'scope's vertical sensitivity is set to 10 mV/div while the time scale is set to 5 ms/div. The coil has 20 turns of wire and a radius of 1 cm. The radius of the wire (28 gauge) is 0.165mm. Calculate the magnitude of the magnetic field responsible for this signal.



8. Resistance and Current

Determine the resistance (R2 below) of the Beakman's motor coil in the previous question. The coil also has an inductance (L1). The best approximate formula for the inductance of such a coil is $L \cong \mu_o N^2 R\ \{\ln(8R/a) - 2\}$ H, where R is the radius of the coil and a is the radius of the wire. Determine the inductance of the coil. Is the impedance of this inductance significant at the frequency of the motor? Explain your answer. Plot the current as a function of time for this motor (on the next page).



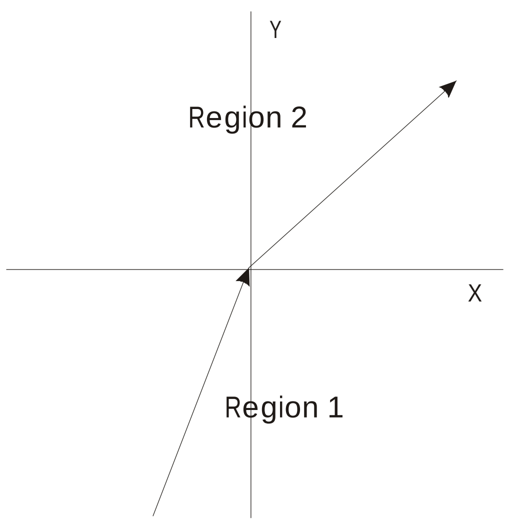
9. Transmission Lines (Circle the correct answers)

The input impedance of an open-circuited transmission line (no load connected to it) will be equal to ∞ for lengths of ($\lambda/4$, $\lambda/2$, $3\lambda/4$, λ, $5\lambda/4$, $3\lambda/2$).

The input impedance of an open-circuited transmission line will be equal to zero for lengths of ($\lambda/4$, $\lambda/2$, $3\lambda/4$, λ, $5\lambda/4$, $3\lambda/2$).

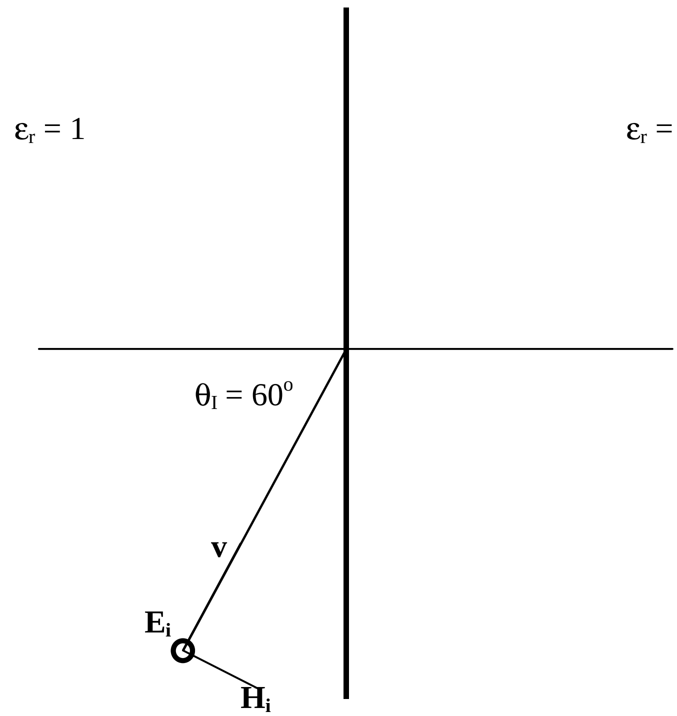
10. Boundary Conditions

Shown below is an electric field line which changes direction at the y = 0 boundary. Given that the angle between the y-axis and the field vector is 20^o in Region 1 and 45^o in Region 2 and that Region 1 is air and Region 2 is an insulator, find the dielectric constant ε_r of the insulator.



Part Two: Longer Questions
2. Electromagnetic Waves

A perpendicularly polarized wave is incident upon a dielectric interface at an angle of 60^o. The amplitude of the incident wave is 1 V/m. The angular frequency $\omega = 2\pi \times 3 \times 10^9$ radians. You can leave your answers in terms of parameters, but all parameters must be evaluated in terms of the given quantities.



a. What is the transmitted wave angle?

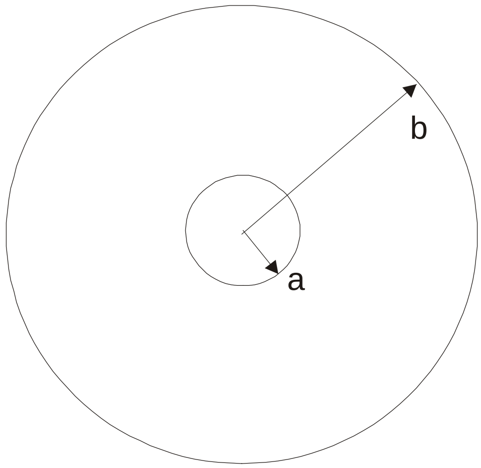
b. What is the reflection coefficient Γ?

c. Write the incident and reflected electric field vectors in phasor form.

d. Write the corresponding magnetic field vectors in phasor form.

e. What fraction of the incident power is reflected?

3. Magnetic Fields



A coaxial cable has a total current I flowing as a surface current density flowing in the + z direction at the radius r = a. This current can be written generally as $\vec{J}_s = J_{sa}\hat{a}_z$ There is no current in the region between r = a and r = b. At r = b, there is a surface current $\vec{J}_s = -J_{sb}\hat{a}_z$.

a. Determine J_{sa} and J_{sb} in terms of a, b and I.

b. Find the magnetic field **B**(r,ϕ,z) of the everywhere in space (for all radii).

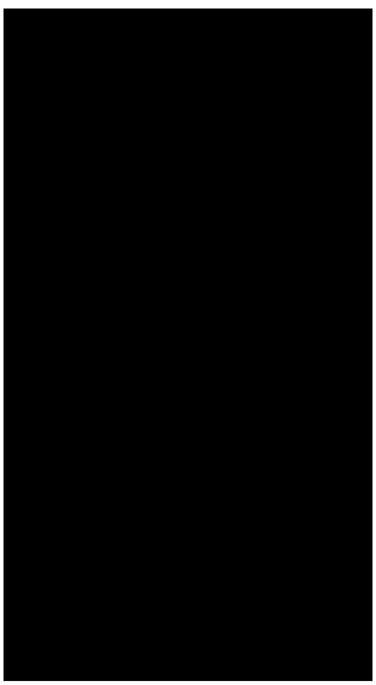
c. Assume that the cable is 10 meters long. Determine the total magnetic flux in the region between r = a and r = b for the entire cable.

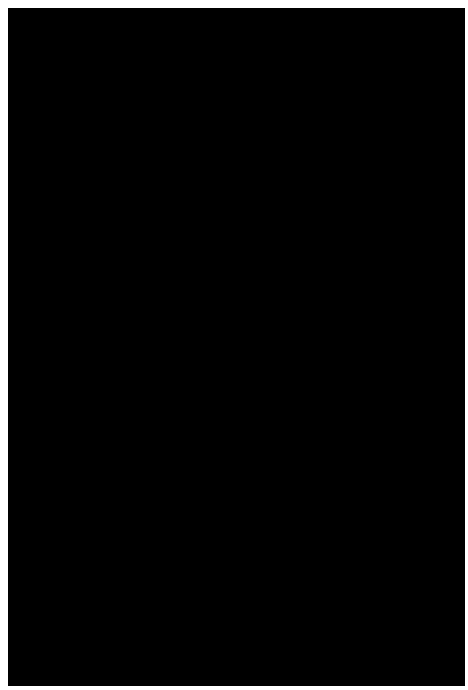
d. Determine the total energy stored in the magnetic field

e. Determine the total inductance of the coaxial cable using both the flux and energy methods.

Reference Materials

Prefix	Symbol	Multiplier
atto	a	10^{-18}
femto	f	10^{-15}
pico	p	10^{-12}
nano	n	10^{-9}
micro	μ	10^{-6}
milli	m	10^{-3}
centi	c	10^{-2}
deci	d	10^{-1}
deka	da	10^{1}
hecto	h	10^{2}
kilo	k	10^{3}
mega	M	10^{6}
giga	G	10^{9}
tera	T	10^{12}





Basic Properties	if $n = a + jb = c\angle\theta$, then
$\pm j^2 = \mp 1$	$n = \sqrt{a^2+b^2}\, e^{j\theta} \quad \theta = \tan^{-1}\dfrac{b}{a}$
$(-j)(j) = 1$	$n n^* = a^2 + b^2 = c^2$
$j = \dfrac{1}{-j}$	$n + n^* = 2a$
$e^{\pm j\pi} = -1$	$n - n^* = j2b$
$e^{\pm j\frac{\pi}{2}} = \mp j$	$\dfrac{n}{n^*} = 1\angle 2\theta$
$\sqrt{j} = \dfrac{\sqrt{2}}{2}(1+j)$	$n^k = (a+jb)^k = (c e^{j\theta})^k = c^k e^{jk\theta}$

Material Properties

	Typical Values
Material	**Property**
Silver	$\sigma = 6.2 \times 10^7$ S/m
Copper	$\sigma = 5.8 \times 10^7$ S/m
Gold	$\sigma = 4.1 \times 10^7$ S/m
Aluminum	$\sigma = 3.5 \times 10^7$ S/m
Seawater	$\sigma = 4$ S/m
Distilled Water	$\sigma \approx 10^{-4}$ S/m
Water	$\mu_r = 0.99999$
Copper	$\mu_r = 0.99999$
Silver	$\mu_r = 0.99998$
Gold	$\mu_r = 0.99996$
Air	$\mu_r = 1.000004$
Aluminum	$\mu_r = 1.000021$
Nickel	$\mu_r = 600$
Mild Steel	$\mu_r = 2000$
Iron	$\mu_r = 5000$
Mumetal	$\mu_r = 100000$
Fused Quartz	$\varepsilon_r = 3.8$
Plexiglass	$\varepsilon_r = 2.8$
Teflon	$\varepsilon_r = 2.1$
Pyrex Glass	$\varepsilon_r = 4.5$
Polyethylene	$\varepsilon_r = 2.3$
Polystyrene	$\varepsilon_r = 2.6$
Air	$\varepsilon_r = 1.00054$
Water	$\varepsilon_r = 78$
Styrofoam	$\varepsilon_r = 1.03$