FINAL EXAM REVIEW

1. Short Questions (4 Points)
- **a.** (0.4 Points) ____
- **b.** (0.4 Points) ____
- **c.** (0.4 Points) ____
- **d.** (0.4 Points) ____
- **e.** (0.4 Points) ____
- **f.** (0.4 Points) ____
- **g.** (0.4 Points) ____
- **h.** (0.4 Points) ____
- **i.** (0.4 Points) ____
- **j.** (0.4 Points) ____

Total _______

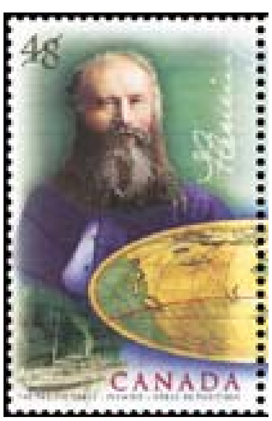
2. Electric Fields (4 Points) _______

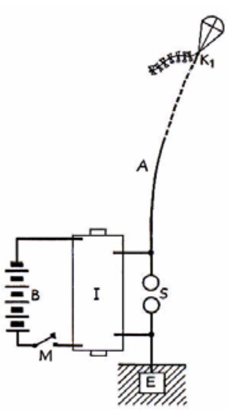
3. Magnetic Fields (4 Points) _______

4. Transmission Lines (4 Points) _______

5. Electromagnetic Waves (4 Points) _______

Total (20 Points) _______

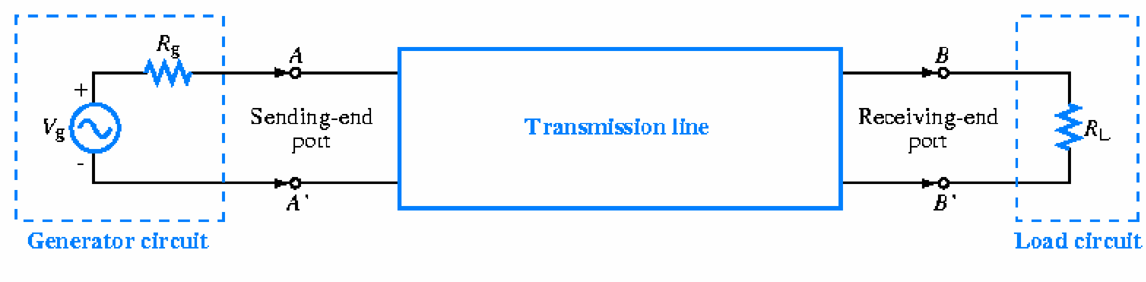





Name ____________________

1. Short Questions (4 Points)

a. (0.4 Points) Transmission Lines

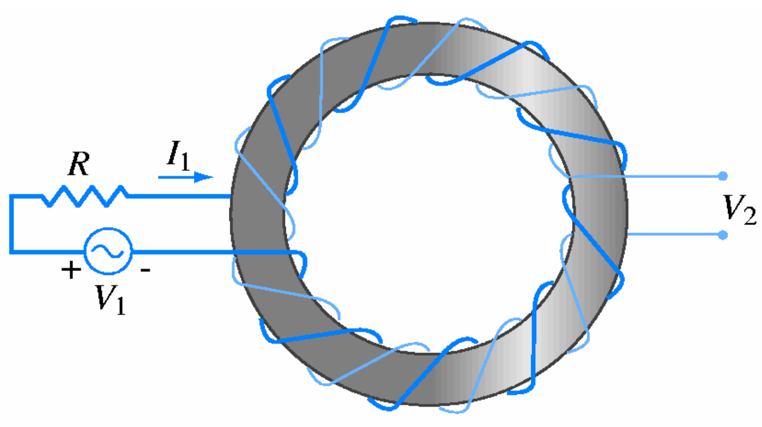


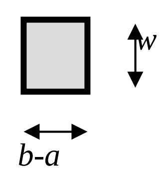
A 100 meter long air insulated, lossless transmission line has a short circuit at its load end. The characteristic impedance of the line is $Z_o = 100$ and the propagation speed is $u = 2x10^8\ m/s$ At low frequencies (near $\omega = 0$), it is possible to significantly simplify the expression for the input impedance of the line. Which of the following is the best approximation for Z_{in} if we simplify it as much as possible?

$$Z_{in} = Z_o \frac{Z_L + jZ_o \tan \beta d}{Z_o + jZ_L \tan \beta d} \qquad Z_{in} = Z_o \qquad Z_{in} = 0 \qquad Z_{in} = jZ_o \frac{\omega}{u} d \qquad Z_{in} = jZ_o u$$

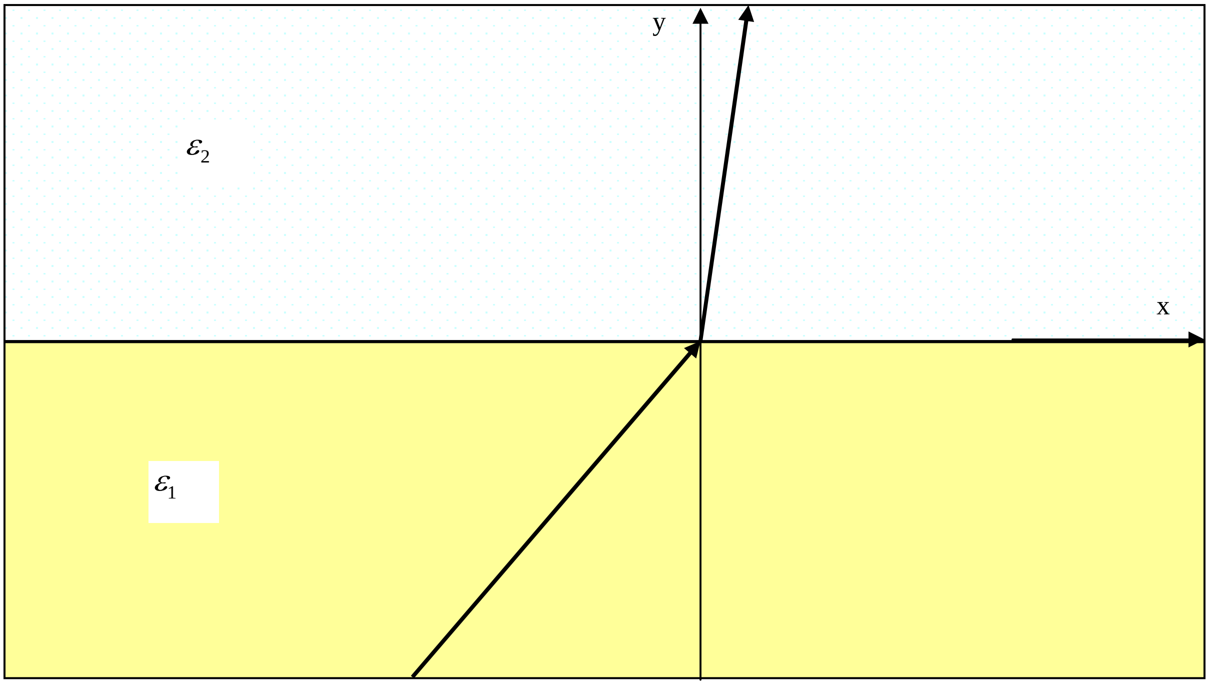
b. (0.4 Points) Magnetic Circuits

An N turn coil is wound on a square cross section torus of permeability μ. If the inner radius of the torus is *a*, the outer radius is *b*, and the depth of the coil is *w*, what is the reluctance of the magnetic circuit? You can assume that $b > a >> (b-a)$ and $b > a >> w$





c. (0.4 Points) Electric Fields



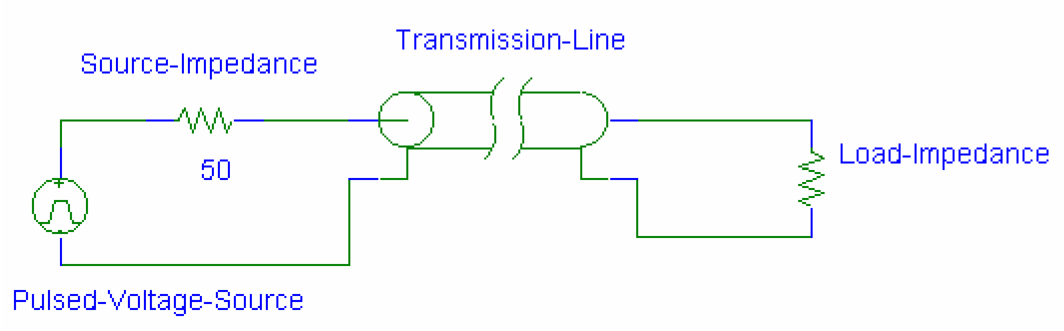
Region 1 is air. The electric field in region 1 is $\vec{E}_1 = E_o\left(\hat{a}_x + \hat{a}_y\right)$. The permittivity in region 2 is $\varepsilon_2 = 6\varepsilon_o$. What is the electric field in region 2 $\vec{E}_2 = ?$.

d. (0.4 Points) Finite Difference Solution to Laplace's Equation

The array shown below is part of a spreadsheet, finite difference solution for a capacitor with a heart-shaped electrode. (The shape of the electrode has nothing to do with this problem.) There are no electrodes or other material boundaries in the region shown. Because only two significant digits are displayed, it appears that the values in some cells do not obey the correct relationship to their neighbors. Identify one cell that is correct and one that is not by circling and labeling them.

47	59	69	79	89	99
41	51	61	70	80	89
36	45	53	62	70	79
31	38	45	53	60	68
25	32	38	44	50	56
20	25	30	35	39	44

e. (0.4 Points) Transmission Lines



A 400 meter long transmission line with $Z_o = 50\Omega$ and $u = 2x10^8 \, {}^{m}\!/_{s}$ connected a pulsed voltage source to a resistive load. A single pulse (magnitude = V_o, duration = $1\mu s$) is emitted from the source. The source impedance is 50Ω If the load resistance $R_L = 1M\Omega$, what voltage is observed at the load? Plot $V_L(t)$.

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

f. (0.4 Points) Electromagnetic Waves (Circle the correct answers.)

- The distance between two adjacent maxima in a standing wave pattern is
  $\lambda/4$, $\lambda/2$, λ, 2λ
- A uniform plane wave is incident obliquely at 25^o on the surface of a large piece of glass ($\varepsilon_r = 6$). 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.

g. (0.4 Points) Transmission Lines (Circle the correct answer or answers)
A standard RG/58 cable is built with a new experimental insulator that has a dielectric constant 9 times that of solid polyethylene. What are the characteristic impedance and propagation velocity for this modified cable?

$Z_o = 50\Omega$ and u=2x10^8 m/s $Z_o = 75\Omega$ and u=1.5x10^8 m/s

$Z_o = 16.7\Omega$ and u=2x10^8 m/s $Z_o = 16.7\Omega$ and u=6.7x10^7 m/s

$Z_o = 25\Omega$ and u=1x10^8 m/s

h. (0.4 Points) Capacitance (Circle the correct answer or answers)
Find the capacitance per unit length of a coaxial cable insulated with Polyethylene. The inner radius of the cable is 1mm and the outer radius is 4mm.

9.0x10^{-11} F/m 3.33x10^{-13} F/m 7.5x10^{-13} F/m 1.48x10^{-13} F/m 4.0x10^{-11} F/m

i. (0.4 Points) Force and Energy
If the magnetic energy density on one side of a boundary between two magnetic, non-conducting materials is higher than the magnetic energy density on the other side of such a boundary,

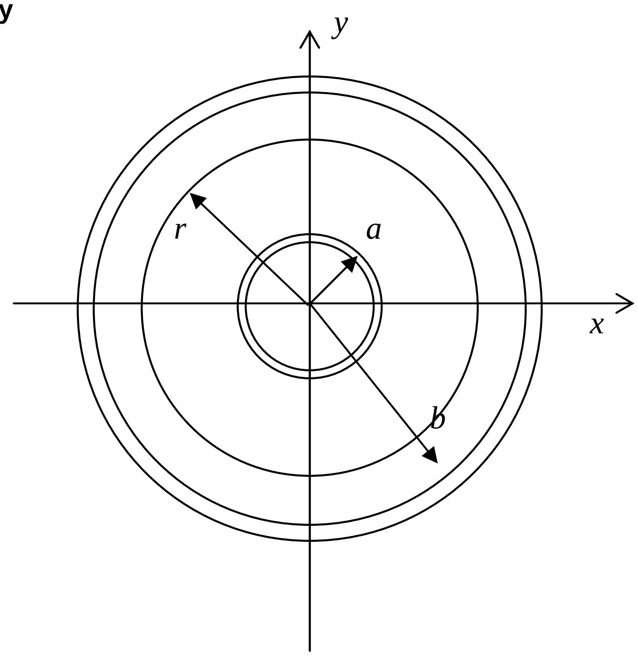
- there will be a force on the boundary toward the region with the higher energy density.
- there will be a force on the boundary toward the region with the lower energy density.
- there is not enough information to tell which direction the force will be.

j. (0.4 Points) Laplace’s Equation
Which of the following statements are correct?

- The value of a function that is a solution to Laplace's equation is equal to the average of the values at its nearest neighboring points.
- The solution to Laplace's equation in some region in space achieves its maximum and minimum values on the boundary of the region.
- Poisson's Equation becomes Laplace's Equation in any region with no volume charge.
- Laplace's Equation is a second order partial differential equation.
- Coulomb's Law for the electric scalar potential is not a solution to Laplace's equation.

2. Electric Fields (4 Points)

An air insulated coaxial cable is constructed as shown at the right with a hollow center conductor of radius *a* and a hollow outer conductor of radius *b*. Both conductors are very thin (assume they are constructed using a very thin foil). The voltage on the inner conductor is V_o and the outer conductor is grounded. The load end of the cable is connected to a resistor *R*. In this problem, we are interested in finding the value of the vector field at a radius *r* in the region between *a* and *b*. A dashed line is shown at the radius of interest.



a. Write down the appropriate Maxwell's Equation to find the field at *r*.

b. Using the equation from part a, determine the electric flux density $\vec{D}(r,\phi,z)$ in the region between the conductors ($a < r < b$)

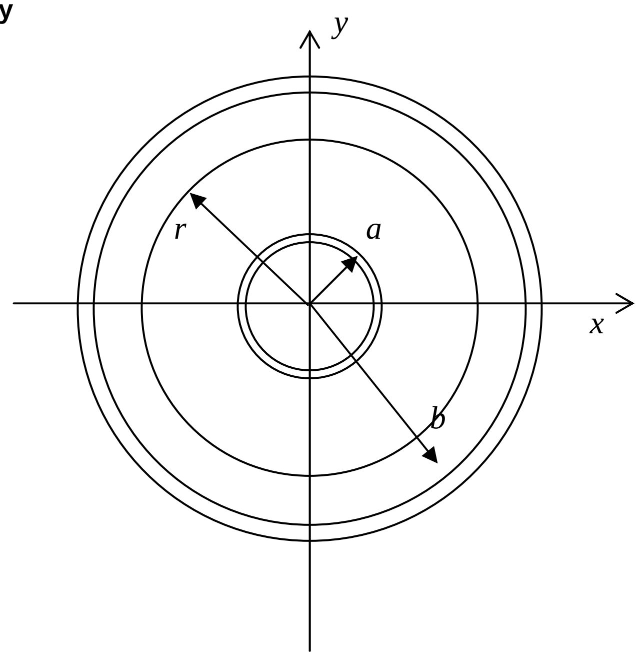
c. Determine the electric field $\vec{E}(r,\phi,z)$ in the same region.

d. Determine the surface charge density on the conductors. Indicate clearly where your answers are valid.

e. Determine the capacitance per unit length of this cable. Indicate which method you have used.

2. Magnetic Fields (4 Points)

An air insulated coaxial cable is constructed as shown at the right with a hollow center conductor of radius *a* and a hollow outer conductor of radius *b*. Both conductors are very thin (assume they are constructed using a very thin foil). The voltage on the inner conductor is V_o and the outer conductor is grounded. The load end of the cable is connected to a resistor *R*. In this problem, we are interested in finding the value of the vector field at a radius *r* in the region between *a* and *b*. A dashed line is shown at the radius of interest.



a. Write down the appropriate Maxwell's Equation to find the field at *r*.

b. Using the equation from part a, determine the magnetic field intensity $\vec{H}(r,\phi,z)$ in the region between the conductors ($a < r < b$)

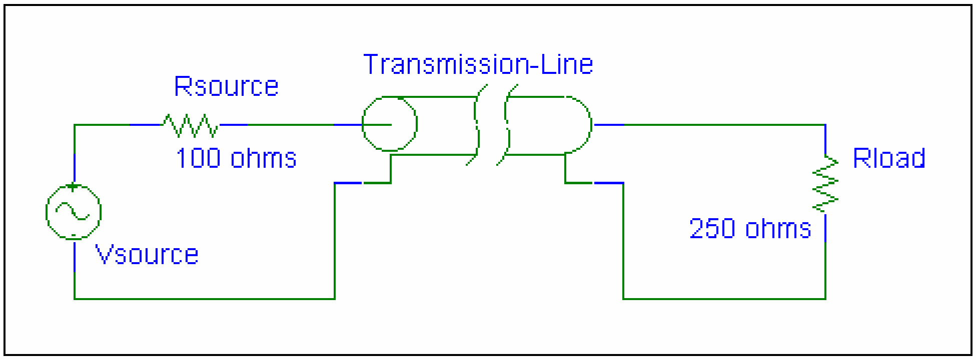
c. Determine the magnetic flux density $\vec{B}(r,\phi,z)$ in the same region.

d. Determine the surface current density in the conductors (the conductors are so thin that they can be considered to carry surface currents). Indicate clearly where your answers are valid.

e. Determine the inductance per unit length of this cable. Indicate which method you have used.

4. Transmission Lines (4 Points)

A lossless transmission line is connected to a resistive load as shown. The frequency of the voltage source is *10 MHz* and its amplitude is *1 V*. The characteristic impedance of the line is 50Ω, the length of the line is *40 meters*, the phase velocity is $4/3 \times 10^8$ *m/s.*



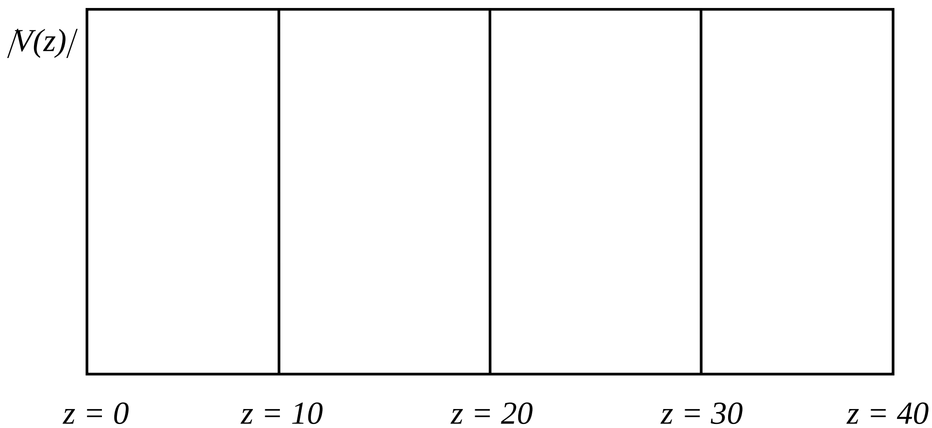
a. Determine the wavelength λ in the transmission line.

b. Determine the input impedance of the line.

c. Determine the magnitude of the voltage at the input and the load.

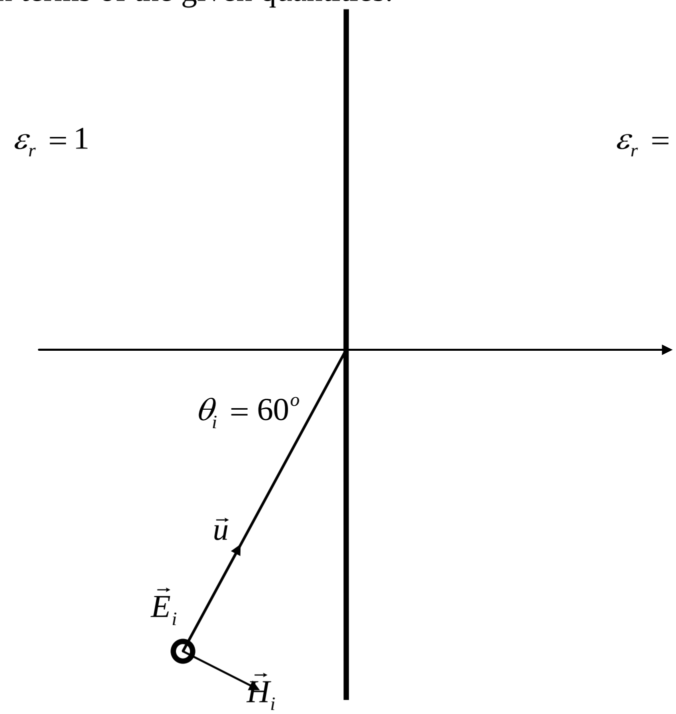
d. Determine the average power delivered to the load.

e. Draw the standing wave pattern for the voltage. Be sure you label your plot with numerical values.



5. Electromagnetic Waves (4 Points)

A perpendicularly polarized wave is incident upon a dielectric interface at an angle of *60°*. The amplitude of the incident wave is *1 V/m*. The angular frequency $\omega = 6\pi x 10^9$ 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?

Material Properties (from Ulaby Appendices)

Dielectric Materials

Material	ε_r	Material	ε_r
Vacuum	1	Dry Soil	2.5-3.5
Air (sea level)	1.006	Plexiglas	3.4
Styrofoam	1.03	Glass	4.5-10
Teflon	2.1	Fused Quartz	3.8-5
Petroleum Oil	2.1	Bakelite	5
Wood (Dry)	1.5-4	Porcelain	5.7
Paraffin	2.2	Formica	6
Polyethylene	2.25	Mica	5.4-6
Polystyrene	2.6	Ammonia	22
Paper	2-4	Sea Water	72-80
Rubber	2.2=4.1	Distilled Water	81
Most Metals	1	All are low frequency values at room temperature (20^{o}C)	

Conductors

Material	$\sigma\, S/m$	Material	$\sigma\, S/m$
Conductors		*Semiconductors*	
Silver	6.2x10^7	Pure Germanium	2.2
Copper	5.8x10^7	Pure Silicon	4.4x10^{-4}
Gold	4.2x10^7	*Insulators*	
Aluminum	3.5x10^7	Wet Soil	10^{-2}
Tungsten	1.8x10^7	Fresh Water	10^{-3}
Zinc	1.7x10^7	Distilled Water	10^{-4}
Brass	1.5x10^7	Dry Soil	10^{-4}
Iron	1x10^7	Glass	10^{-12}
Bronze	1x10^7	Hard Rubber	10^{-15}
Tin	0.9x10^7	Paraffin	10^{-15}
Lead	0.5x10^7	Mica	10^{-15}
Mercury	0.1x10^7	Fused Quartz	10^{-17}
Carbon	3x10^4	Glass	10^{-17}
Sea Water	4		
Animal Body	0.3	All are low frequency values at room temperature (20^{o}C)	

Magnetic Materials

Material	μ_r	Material	μ_r
Diamagnetic		Titanium	$1.0002 \approx 1$
Bismuth	$0.99983 \approx 1$	Platinum	$1.0003 \approx 1$
Gold	$0.99996 \approx 1$	*Ferromagnetic*	*Nonlinear*
Mercury	$0.99997 \approx 1$	Cobalt	250
Silver	$0.99998 \approx 1$	Nickel	600
Copper	$0.99999 \approx 1$	Mild Steel	2000
Water	$0.99999 \approx 1$	Iron (Pure)	4000-5000
Paramagnetic		Silicon Iron	7000
Air	$1.000004 \approx 1$	Mu Metal	~100,000
Aluminum	$1.00002 \approx 1$	Purified Iron	~200,000
Tungsten	$1.00008 \approx 1$	Only typical values, actual values depend on material variety	