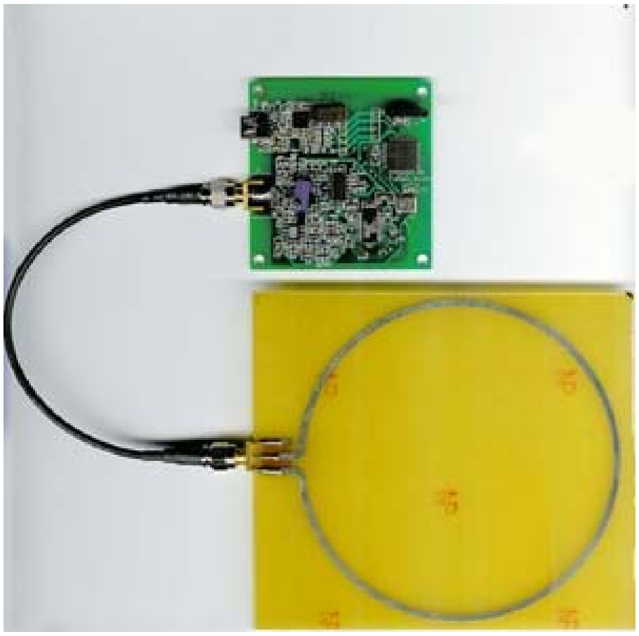
Quiz 3
23 April 2007

MAGNETIC FIELDS & UNIFORM PLANE WAVES



Name ________________________

Section ________________________

Multiple Choice

1. (8 Pts) ____________
2. (8 Pts) ____________
3. (8 Pts) ____________
4. (8 Pts) ____________
5. (8 Pts) ____________

Regular Questions

6. (20 Pts) ____________
7. (20 Pts) ____________
8. (20 Pts) ____________

Total (100 Pts) ____________

Notes:
1. In the multiple choice questions, each question may have more than one correct answer; circle all of them.
2. For multiple choice questions, you should add some comments to justify your answer.
3. Make sure your calculator is set to perform trigonometric functions in radians & not degrees.

Some Comments and Helpful Info:
In this test, we use two types of notation for unit vectors. Keep in mind that

$\hat{a}_x = \hat{x}$ $\hat{a}_y = \hat{y}$ $\hat{a}_z = \hat{z}$ $\hat{a}_r = \hat{r}$ $\hat{a}_\phi = \hat{\phi}$ $\hat{a}_\theta = \hat{\theta}$

Be sure to show your work for the multiple choice questions.
Draw pictures for each problem to be sure that you understand the problem statement.

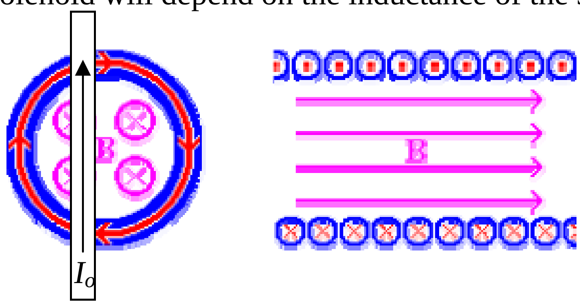
Quiz 3
23 April 2007

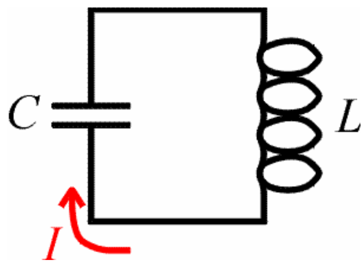
MULTIPLE CHOICE QUESTIONS

Remember, there can be more than one answer to any of the short questions.

1. Force (8 points)

An actuator is constructed by placing a wire through a solenoid as shown below. This wire carries a fixed current I_o. The solenoid is driven by a capacitor which has been charged up to some voltage V_o. Since the energy available to provide current to the solenoid comes entirely from the capacitor, the current in the solenoid and the resulting magnetic field in the solenoid will depend on the inductance of the solenoid.





If we are free to wind the solenoid with any number of turns, which of the following will produce the maximum force on the wire? Explain your answer.

a. $N = 100$ turns
b. $N = 500$ turns
c. $N = 1000$ turns
d. *All three choices*
e. *None of the choices*

2. Shielding (8 points)

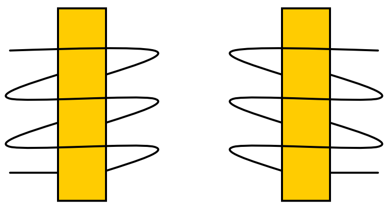
In order to prevent the electric and magnetic fields from entering or leaving a room, the walls of the room are shielded with 1-mm thick aluminum foil. For which of the following frequencies (if any) will the room be reasonably well shielded?

a. 1 Hz
b. 1 kHz
c. 1 MHz
d. 1 GHz
e. No difference

Quiz 3
23 April 2007

3. Mutual Inductance (8 Points)
Assume that we have two identical circular coils, each wound with *N* turns. Which configuration will have the maximum and which will have the minimum mutual inductance? For each case, the coils are wrapped around identical magnetic materials. The distance between the coils is larger for *b* and *c* than for *a* and *d*.

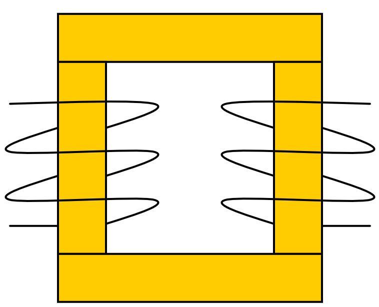
a



b

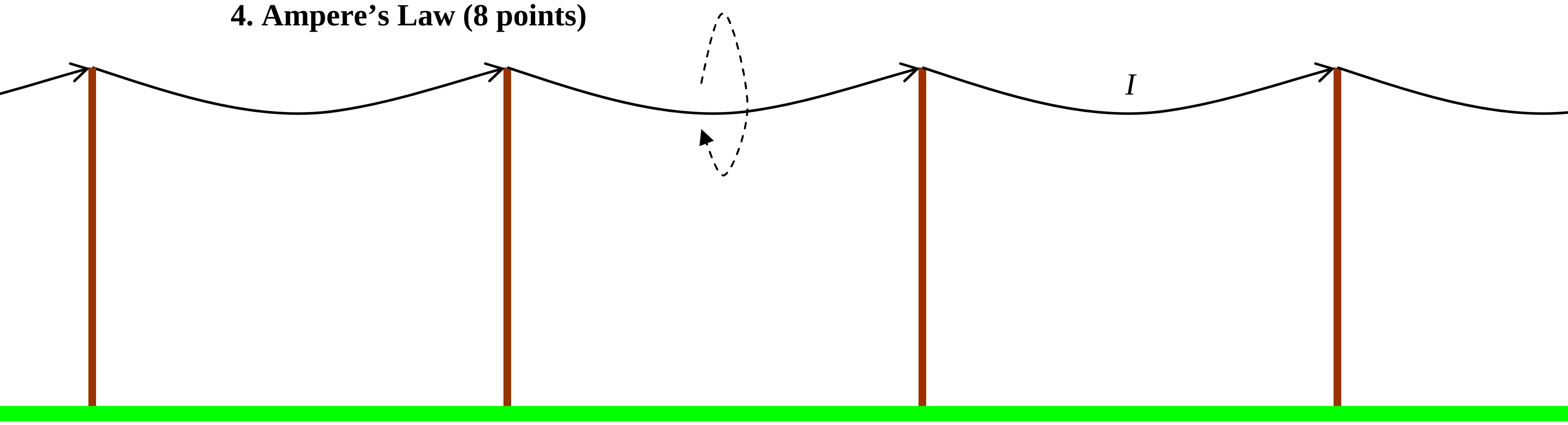
c

d



a. Figure *a* will have the maximum and figure *d* will have the minimum
b. Figure *c* will have the maximum and figure *b* will have the minimum
c. Figure *d* will have the maximum and figure *c* will have the minimum
d. Figure *b* will have the maximum and figure *a* will have the minimum
e. Cannot tell

4. Ampere's Law (8 points)



For an early telegraph line, the current in the line I is carried to the right in the wire and returns through the ground. If one applies Ampere's Law to the dashed loop surrounding the telegraph wire, which of the following describes the integral of the magnetic field intensity H around the loop?

a) $\mu_o I$
b) $-\mu_o I$
c) greater than $\mu_o I$
d) less than $-\mu_o I$
e) less than $\mu_o I$ and positive
f) greater than $-\mu_o I$ and negative
g) zero

5. Applications of Fields and Waves I (8 points)

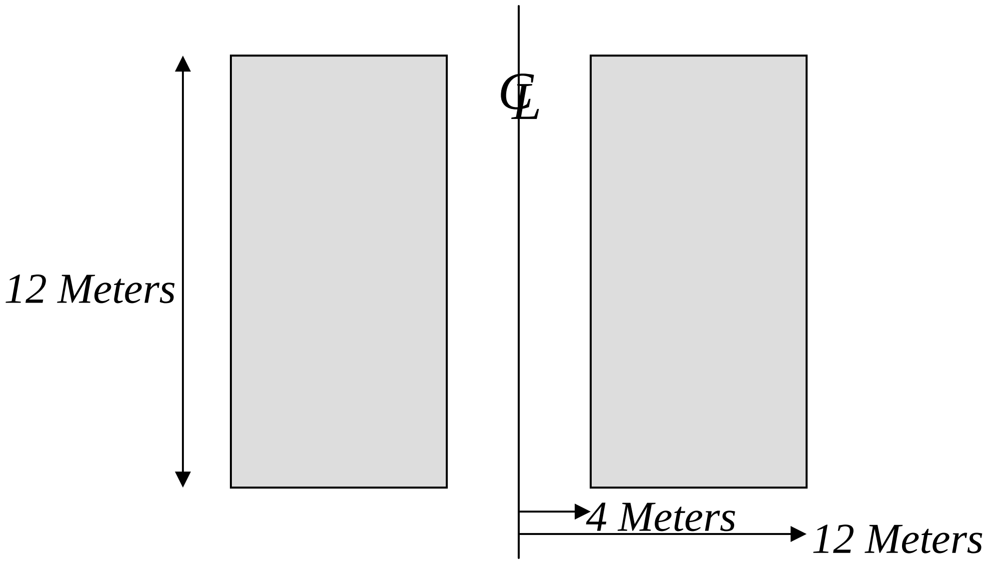
Lower frequency RFID coil circuits must be designed to be resonant to be effective. Which of the following is a correct description of the how this resonant circuit is constructed? *You might want to sketch the circuit.*

a) a resistor is placed in series with the coil. The value of the resistor is chosen to be identical to the inductive impedance of the coil at the resonant frequency. The resonant frequency of this circuit is thus determined by its total resistance and inductance.
b) an inductor is placed in parallel with the coil. The value of the inductor is chosen to be the inverse of the inductance of the coil. The resonant frequency of the circuit is determined by value of the inductance.
c) a capacitor is placed in parallel with the coil. The value of the capacitor is chosen so that the combination of the capacitance and inductance determines the resonant frequency.
d) the coil is mounted on a plate that vibrates at the desired resonant acoustic frequency. The frequency is determined entirely by the mechanical properties of the plate.
e) the rate at which the transmitting and receiving circuits are programmed to send and receive signal pulses determines the so called resonant frequency of the system
f) all of the above
g) none of the above

Quiz 3
23 April 2007

REGULAR QUESTIONS
6. Ampere's Law & Inductance (20 points)

A very large air core toroidal magnet is constructed with N turns of wire carrying a current I. The torus is rectangular in cross section as shown below. Note, the dimensions of the toroid are such that the magnetic field cannot be assumed constant. For your solution, assume that $N = 40{,}000$ *turns* and $I = 1000$ *Amps*.



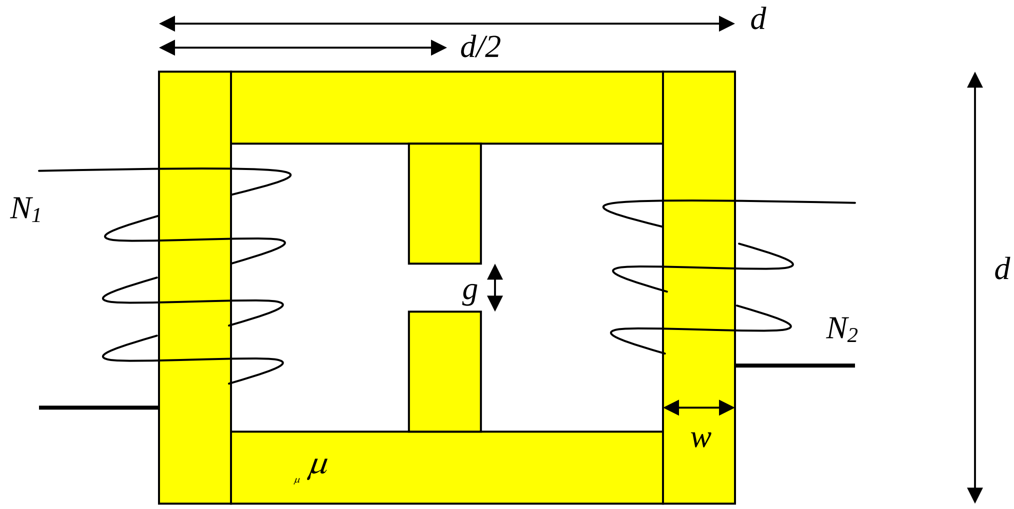
a. What is the magnetic field intensity vector $\vec{H}$ inside the gray region ($4<r<12$) and ($0<z<12$)? (5)

b. How much magnetic flux is found in a typical cross section and what is the total flux linked by the toroidal coil? (5)

c. How much energy is stored in the toroidal region where the magnetic field is non-zero? (5)

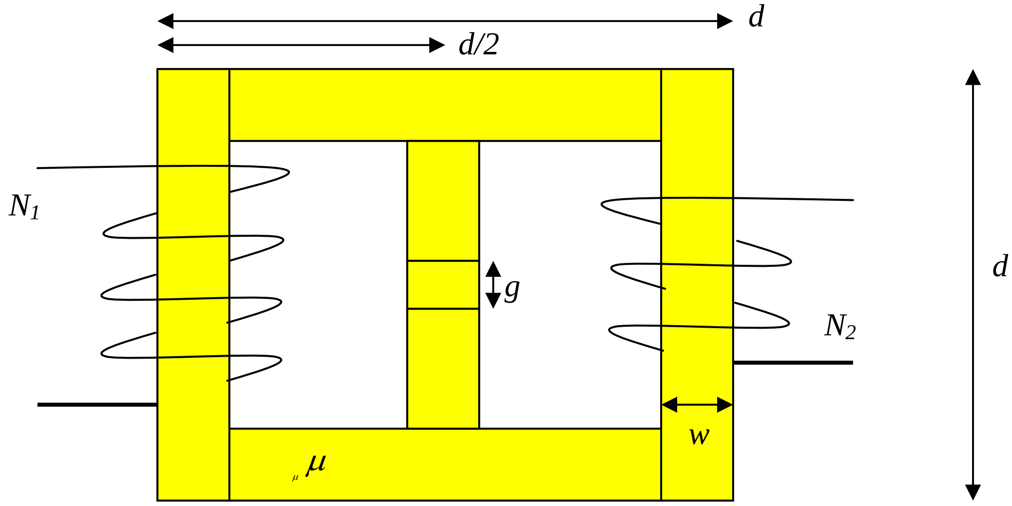
d. What is the external inductance of the toroid? (5) *You are free to use either the flux or energy method to solve for this.*

7. **Magnetic Circuit and Faraday's Law (20 Points)**
The magnetic core configuration shown below is to be used to read data off of a bar of material. The bar consists of alternating magnetic and nonmagnetic sections of material and will pass through the gap in the core. All the legs of the core have a width *w* and the depth of each piece is also *w*. The size of the gap *g* is assumed to be very small.

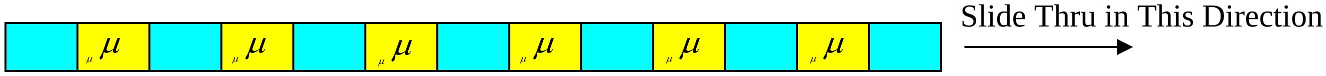


a. Assuming a current *I* in the coil at the left, determine the magnetic flux in each of the three legs of the magnetic circuit. (5) You may make any reasonable assumptions.

b. Now assume that the gap has been filled with a magnetic material with the same permeability μ as the core (see next page). Again, determine the magnetic flux in each of the three legs of the magnetic circuit. (5)



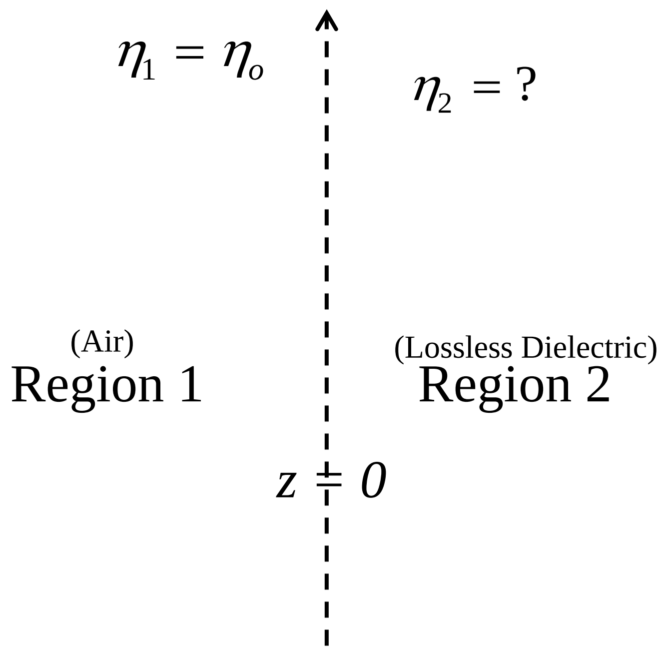
c. Assume that the bar below is passed through the gap so that the cap is alternately filled with a magnetic material with permeability μ and an insulator with permittivity ε. Make an approximate sketch of the magnetic flux density $\vec{B}$ as a function of time. It is not necessary to get every detail correct, only the general form of the observed field. It is possible to measure such fields by embedding a Hall Effect Gauss Meter probe in the magnetic material. (5)



d. Determine the inductance of the coil at the left for both cases. (5)

8. Uniform Plane Waves in Lossless and Materials (20 Points)

A uniform plane wave is propagating in air and incident normally on a lossless dielectric medium. The frequency of the wave is 900MHz. The average power density of the wave is 1000 Watts per square meter. You might find it helpful to draw the vector diagram for each wave to be sure you have the directions correct. You do not have to simplify any expression (you can leave it in terms of parameters), except for part f, which requires a number.



a. Determine the angular frequency ω, the propagation constant β, and the wavelength λ for this incident wave. (3)

b. Determine the magnitude of the incident electric field and both the full phasor expressions for incident magnetic field. (5)

c. Assume that 15% of the incident power is reflected from the interface at $z = 0$. Determine the dielectric constant of the lossless dielectric medium that fills the region $z > 0$. Remember that your answer must be realistic. From this answer determine the intrinsic impedance of the dielectric medium. (7)

d. Write the phasor vector form of the reflected and transmitted magnetic fields. (5)

Quiz 3
23 April 2007

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^oC)	

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^oC)	

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	