NAME: ____________________________________

ECE 6340
Fall 2007

EXAM I

INSTRUCTIONS:

This exam is open-book and open-notes. You may use any material or calculator that you wish.

Put all of your answers in terms of the parameters given in the problems, unless otherwise noted.

Include units with all answers in order to receive full credit.

Please write all of your work on the sheets attached.

Please show *all of your work* and *write neatly* in order to receive credit.

Useful identity:

$$\sin^2(x) = \frac{1-\cos(2x)}{2}$$

Problem 1 (40 pts)

An air-filled semi-infinite rectangular waveguide is operating (above the cutoff frequency) in the TE_{10} mode. The end of the waveguide at $z = 0$ has a short circuit (metal plate). The metal is perfecting conducting (both the waveguide walls and the short-circuit plate) and the air inside the waveguide is lossless. The electric field inside of the waveguide is

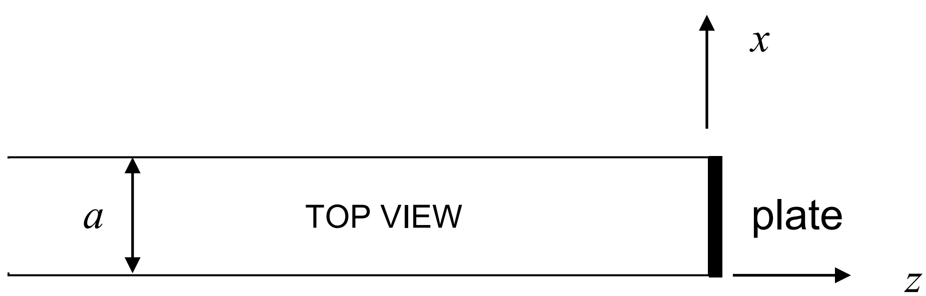
$$\underline{E}(x,y,z) = \underline{\hat{y}} \sin\left(\frac{\pi x}{a}\right) \sin(k_z z),$$

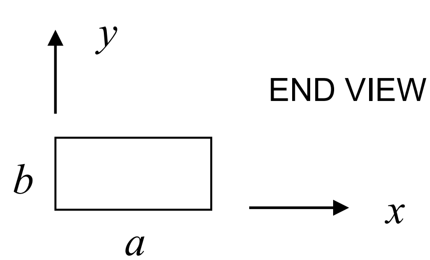
where

$$k_z = \sqrt{k_0^2 - \left(\frac{\pi}{a}\right)^2}.$$

Since we are above cutoff, k_z is a positive real number.

1) Calculate the magnetic field inside the waveguide.
2) Calculate the complex power that is flowing in the positive z direction down the waveguide at $z = -L$.
3) Calculate the time-average energy stored in the electric field inside of the waveguide, in the region $-L < z < 0$.
4) Use the complex Poynting theorem to help you determine what the time-average energy stored in the magnetic field is, for this same region.





ROOM FOR EXTRA WORK

Problem 2 (30 pts)

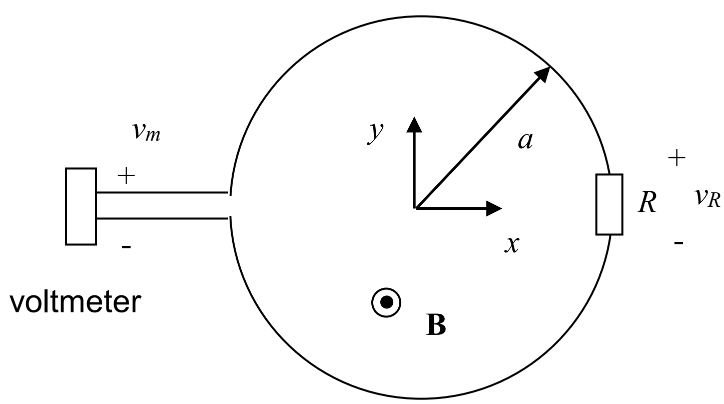
A voltmeter is connected to a resistor R as shown below. The resistor is part of some circuit (but the rest of the circuit is not shown). The resistor is not moving. The leads coming out of the voltmeter stay on the perimeter of a circle that has a radius a, and they are perfectly conducting. Everywhere in space there is a magnetic field of the form

$$\underline{B} = \underline{\hat{z}}\, B_0 \cos(\omega t).$$

Assume that the magnetic field does not affect the voltmeter (which is not moving). That is, the voltmeter reading $v_m(t)$ is the correct voltage drop between the input terminals of the voltmeter.

1) The voltmeter reads a voltage of $v_m(t)$. Derive a formula for what the actual voltage across the resistor $v_R(t)$ is, in terms of $v_m(t)$.

2) Now assume that the resistor is moving with a velocity $v = \underline{\hat{x}}\, v_0$ where v_0 is a constant. How would the answer for $v_R(t)$ (in terms of $v_m(t)$) change? Assume that the leads remain on a circular boundary of radius a, where a is now a function of time (since the leads remain connected to the resistor). The leads are thus made out of an "expandable" material. Assume that the length of the resistor is L and that the resistor is always vertical (in the y direction) as shown. (You may need this assumption in your derivation.)



ROOM FOR EXTRA WORK

Problem 3 (30 pts)

A glass of distilled water is placed inside of a microwave oven operating at 2.45 GHz. The volume of the water is 0.5 liters (1 liter = 0.001 m^3). The electric field inside of the water is

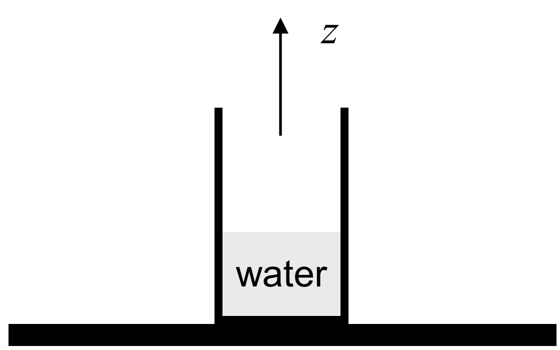
$$\underline{E} = \underline{\hat{z}} \cos(\omega t).$$

The water has a complex relative permittivity $\varepsilon_r(\omega)$ that obeys a Debye model, and has the following static and infinite frequency limits:

$$\varepsilon_r(0) = 81$$
$$\varepsilon_r(\infty) = 15.5.$$

Also, the frequency at which ε_r'' is maximum is 18 GHz.

1) Determine the power dissipation (in watts) for the distilled water.
2) Now assume that the water has salt mixed inside of it. Assume that the complex permittivity $\varepsilon_r(\omega)$ does not change (it is still the same as in part (a)), but now there is also a conductivity present, with σ = 1.0 S/m. How would your answer for the power dissipation change?



ROOM FOR EXTRA WORK