McGill University
Faculty of Engineering

FINAL EXAM
DECEMBER 2002

VERSION A

COURSE ECSE 353
ELECTROMAGNETIC FIELDS AND WAVES

Examiner:	J. P. Webb	Co-Examiner:	S. McFee
Signature:	_____________	Signature:	_____________
Date:	Friday, December 20, 2002	Time:	09:00

- This is a closed book examination. No books or notes are permitted, except for the Formula Sheet attached.
- The Faculty Standard Calculator only is permitted: Casio fx-991 (any extension), Sharp EL-546L or Sharp EL-546R.
- All units are SI unless otherwise stated
- This is a 180 minute exam
- The marks indicated in square brackets at the start of each question are out of 180.

INSTRUCTIONS:

- Answer all questions.
- Put your name and student ID also on the Answer Sheet provided.
- **Part A** is multiple choice. There is one correct answer for each question. Mark your answers on the Answer Sheet, not on this examination paper. Only the answers on the Answer Sheet will be considered.
- **Part B**: Put your answers in the spaces provided on the Answer Sheet.

WHEN INSTRUCTED, TURN TO NEXT PAGE AND START THE EXAM

PART A

Part A is multiple choice. There is one correct answer for each question. Mark your final answers on the Answer Sheet. Only the answers on the Answer Sheet will be considered.

1. [4] When a capacitor is being charged, what kind of current flows from one conductor to the other?
   A Polarization current
   B Conduction current
   C Magnetization current
   D Displacement current

2. [4] Which one of these statements is *not* true:
   A The radiation intensity of an antenna falls off as $1/R^2$ in the far zone
   B The directive gain of an antenna cannot be greater than its directivity
   C An isotropic antenna radiates power equally in all directions
   D An antenna can have a gain greater than 1

3. [4] A uniform plane wave, sinusoidal in time, propagates in the $+y$ direction in air. The magnetic field of this wave at some instant t and position y is $\mathbf{H}(y,t) = -\mathbf{a}_x$. Which of the following statements is true regarding the electric field at the same time and position?
   A It is directed along the $+y$ axis
   B It is directed along the $-y$ axis
   C It is directed along the $+z$ axis
   D It is directed along the $-z$ axis

4. [4] The distance between two equal and opposite charges doubles. What happens to the magnitude of the electric dipole moment of the charges?
   A It is halved
   B It is unchanged
   C It is doubled
   D It increases by a factor of four

5. [4] Inside a resistor, the dot product of electric field and current density, **E**.**J**, is:
   A the work done by the electric field
   B the work done by the electric field, per unit volume
   C the power dissipated as heat
   D the power dissipated as heat, per unit volume

6. [4] What is the unit of the magnetic field intensity, **H**?

TURN TO NEXT PAGE

A A / m^2
B T
C A / m
D Wb

7. [4] A sinuoidal voltage source is connected to one end of a lossless transmission line, and at the other end there is a resistive load. When the amplitude of the voltage along the line is measured, there is found to be a maximum at the load. What can you say about the load resistance?
A nothing
B the load resistance is greater than the characteristic impedance
C the load resistance is less than the characteristic impedance
D the load resistance is equal to the characteristic impedance

8. [4] A transmission line is terminated in a perfect open circuit. What is the reflection coefficient of this load?
A –1
B 0
C +½
D +1

9. [4] When a magnetic field line passes from iron into air, does it
A remain unchanged in direction?
B bend towards the normal to the interface?
C bend away from the normal to the interface?
D bend away or towards the normal, depending on the angle it makes in the iron.

10. [6] A lossless transmission line with characteristic impedance 50Ω is terminated in a complex load 50+j100 Ω. Find the voltage standing wave ratio on the line.
A $3-\sqrt{2}$
B 3
C $3+2\sqrt{2}$
D ∞

TURN TO NEXT PAGE

11. [6] Two long wires are parallel and the distance between their centres is 10cm. Each carries a current of 1A *in the same direction*. Find the magnitude of the flux density exactly half way between the wires, 5cm from the centre of each wire.
A 0
B 4 μT
C 8 μT
D 16 μT

12. [6] Find the *internal* inductance of a circular loop of copper wire. The radius of the loop is 2cm. (The permeability of copper is the same as that of air.)
A 6.3 nH
B 12.6 nH
C 25.1 nH
D 50.2 nH

13. [6] The electrostatic potential of a conducting sphere relative to infinity is V_0. The radius of the sphere is a. Find the total charge on the sphere.
A $4\pi\varepsilon_0 a^2 V_0$
B $4\pi\varepsilon_0 a V_0$
C $2\pi\varepsilon_0 a^2 V_0$
D $2\pi\varepsilon_0 a V_0$

14. [6] A uniform plane wave, propagating in air, is normally incident on an infinite, plane, perfectly-conducting surface. When the electric field strength (amplitude) is measured, starting at the surface and moving outwards, the first maximum is found to be 10cm from the surface. Find the frequency.
A 375 MHz
B 750 MHz
C 1.5 GHz
D 3.0 GHz

TURN TO NEXT PAGE

15. [6] A uniform, steady current density, magnitude J_0, flows in the x direction through a sample of material with a non-uniform conductivity, $\sigma = \sigma_0(1+x)$. The permittivity of the material is the same as that of air. Find the volume charge density in the material.

A $-\dfrac{\varepsilon_0 J_0}{\sigma_0(1+x)^2}$

B $-\dfrac{\varepsilon_0 J_0}{\sigma_0(1+x)}$

C $+\dfrac{\varepsilon_0 J_0}{\sigma_0(1+x)^2}$

D $+\dfrac{\varepsilon_0 J_0}{\sigma_0(1+x)}$

16. [6] The phasor magnetic vector potential, **A**, created in the air by an antenna has just a radial component, A_R (in spherical coordinates R, θ, ϕ). Further, that component varies only with R and θ, not with ϕ. Find the radial component of the phasor electric field, E_R.

A $-\dfrac{1}{\mu_o}\dfrac{1}{R}\dfrac{\partial A_R}{\partial \theta}$

B $-\dfrac{1}{\mu_o}\dfrac{1}{R\sin\theta}\dfrac{\partial A_R}{\partial \theta}$

C $-\dfrac{1}{j\omega\varepsilon_o\mu_o}\dfrac{1}{R}\dfrac{\partial}{\partial R}\left(R\dfrac{\partial A_R}{\partial \theta}\right)$

D $-\dfrac{1}{j\omega\varepsilon_o\mu_o}\dfrac{1}{R^2\sin\theta}\dfrac{\partial}{\partial \theta}\left(\sin\theta\dfrac{\partial A_R}{\partial \theta}\right)$

17. [6] Time-harmonic magnetic flux links a single, closed, turn of copper wire and induces in it a current with an amplitude of 1mA. The resistance of the copper wire is 100Ω and the frequency is 60 Hz. Find the amplitude of the magnetic flux.

A 0.265 mWb
B 100 mWb
C 0.265 Wb
D 100 Wb

TURN TO NEXT PAGE

18. [6] A pulse generator consists of a *current* source in parallel with a 100Ω resistor. When a short circuit is connected across the terminals of the generator, the current pulses that flow through the short circuit have a current amplitude of 1mA. When the short circuit is removed and a lossless transmission line of characteristic impedance 50Ω is used to connect the generator to a load, find the *voltage* amplitude of the pulses launched on the line.

A 0.67 mV
B 16.7 mV
C 33.3 mV
D 50 mV

TURN TO NEXT PAGE

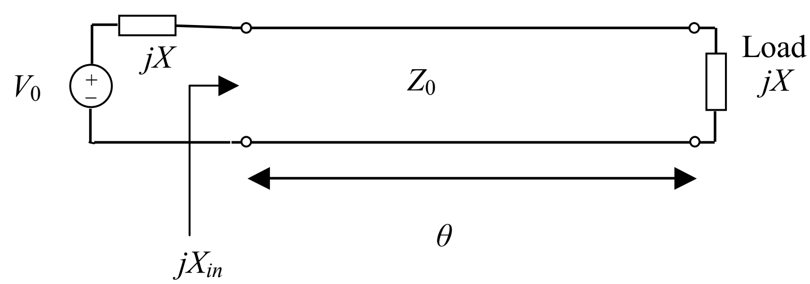
PART B

In Part B, put your answers in the spaces provided on the Answer Sheet.

19. [30] A lossless transmission line has electrical length θ (radians), and has a characteristic impedance of Z_0 (Ω). The load and source impedances are purely reactive, both with impedance jX (Ω). The generator provides a sinusoidal signal with phasor voltage V_0. Find an expressions for:

    (a) the input reactance, X_{in}, at the generator end of the line, in terms of θ, Z_0, and X; and

    (b) the phasor voltage across the load, in terms of X_{in}, θ, Z_0, X and V_0.



20. [30] A coaxial transmission line consists of a circular inner conductor of radius a, and a concentric circular outer conductor of (inner) radius b. Between the conductors is a dielectric with a permittivity ε that varies with radial distance r from the centre of the inner conductor in the following way:

$$\varepsilon = \varepsilon_o + \varepsilon_1 r$$

Find the capacitance per unit length of the transmission line, in terms of a, b, ε_o and ε_1. [Hint: You may find the following formula useful:

$$\frac{1}{(c+dr)r} = \frac{1}{cr} - \frac{d}{c(c+dr)}$$]

21. [30] At 1kHz, a uniform, linearly polarized, plane wave propagating in air is normally incident on a uniform half-space filled with copper (conductivity 5.8×10^7 S/m, permittivity and permeability same as free space). The amplitude of the incident electric field, in the air, is 1 V/m. Find the amplitude of the electric field at a depth of 1mm into the copper.

END OF QUESTIONS **FORMULAS FOLLOW**