State University of New York
University at Buffalo
Department of Mechanical and Aerospace Engineering

MAE 438/538 **Prof. D.D.L. Chung**
May 5, 2004

Final examination
Closed book

This test consists of 14 problems on 4 pages. Answer all questions in the blue book provided.

Problem 1 (30%)

Describe each of the following phenomena

(a) Shape-memory effect
(b) Pseudoelasticity
(c) Ferroelasticity
(d) Magnetorheology
(e) Magnetostriction
(f) Ferrimagnetism
(g) Ferroelectricity
(h) Total internal reflection
(i) Magnetoresistance
(j) Photoconductivity
(k) Pyroelectric effect
(l) Skin effect
(m) Polarization reversal
(n) Dielectric breakdown
(o) Piezoelectric aging

Problem 2 (12%)

What is the main difference between

(a) paramagnetism and ferromagnetism
(b) a stepped index optical fiber and a graded index optical fiber
(c) a hard PZT and a soft PZT
(d) a hard magnet and a soft magnet
(e) a thermocouple and a thermistor
(f) a laser and a light-emitting diode (in terms of the frequency bandwidth)

Problem 3 (10%)

Answer the following questions.

(a) Why is a small magnetic domain size desirable for a magnetostrictive material?
(b) Why is a cladding needed for an optical fiber?
(c) What is the main cause of attenuation loss of an optical fiber?
(d) What is the principle behind an evanescent-wave optical fiber sensor?
(e) Why does the oxygen atom have a magnetic moment, whereas the oxide ion (O_2^-) does not?

Problem 4 (6%)

An optical fiber has a core of refractive index 1.48 and a cladding of refractive index 1.35. (a) What is the critical angle? (b) What is the acceptance angle?

Problem 5 (4%)

What is the magnetic moment in 1 cm^3 of ferrite (Fe_3O_4) that has been fully magnetized?
Hint: The saturation magnetization of ferrite is 5×10^5 $A.m^{-1}$.

Problem 6 (4%)

How many Bohr magnetons of magnetic moment are associated with a samarium (Sm) atom?
Hint: The electronic configuration of Sm is … $4f^6 5d^0 6s^2$.

Problem 7 (4%)

Sketch the variation of the strain with the applied electric field for a ferroelectric material during variation of the electric field from zero to a very positive value, the n from the very positive value to a very negative value (much beyond the coercive field), and then from the very negative value back to the very positive value (much beyond the coercive field).

Problem 8 (4%)

Sketch the variation of the stress with strain during loading and subsequent unloading for a shape-memory alloy at a temperature between A_s and A_f.

Problem 9 (5%)

A laser is required to have a coherent length of 1000 km. Give the maximum frequency bandwidth allowed.

Hint: $x_c = \frac{c}{\Delta v}$

c= $3x10^8 m/s$

Problem 10 (4%)

How many electron-hole pairs are generated in a semiconductor (silicon) detector by a photon of X-ray of energy 1.49 keV, which is the energy associated with the transition of an electron of aluminum from the L energy level to the K energy level? The energy band gap of silicon is 1.1 eV.

Problem 11 (5%)

An optical fiber of length 1.8 km has an attenuation loss of 1.5 dB/km. What is the ratio of the intensity of light exiting the fiber to that entering the fiber at the other end?

Hint: Atteunation loss = -10 log $\frac{I}{I_0}$

Problem 12 (4%)

The polarization is 0.17 C/m^2 in a material of thickness 40 μm and a diameter 600 μm. What is the dipole moment?

Problem 13 (4%)

The piezoelectric coupling coefficient d is 100 x 10^{-12} C/Pa.m^2 (m/V) for $BaTiO_3$. The elastic modulus is 69 GPa. What is the value of the voltage coefficient g for $BaTiO_3$?

Hint: $g = \frac{1}{Ed}$

Problem 14 (4%)

A piezoelectric material with voltage coefficient g of 0.22 m^2/C is subjected to a stress of 48 MPa. How much electric field (in V/m) is generated?

Hint: Electric field = g (stress)