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 (O₂⁻) 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 cm³ of ferrite (Fe₃O₄) that has been fully magnetized?
Hint: The saturation magnetization of ferrite is 5×10⁵ 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 … 4f⁶5d⁰6s².
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, then 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 As and Af.

Problem 9 (5%)

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

Hint: \[ x_c = \frac{c}{\Delta \nu} \]

\[ c = 3 \times 10^8 \text{ m/s} \]

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: \[ \text{Attenuation loss} = -10 \log \frac{I}{I_0} \]

Problem 12 (4%)

The polarization is 0.17 C/m² 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 \( 100 \times 10^{-12} \) 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: \( g = \frac{1}{E_d} \)

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)