Electricity and Magnetism

Do two out the following three problems, each on a separate sheet.
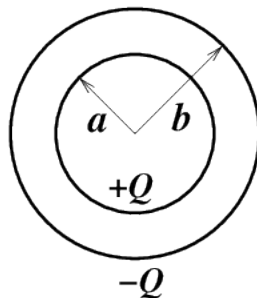
Problem 1

Consider a wire of radius R, that carries a constant current I, uniformly distributed over its cross section. The wire has a narrow gap of width $d \ll R$, which forms a parallel-plate capacitor. Find the (electromagnetic) energy density, u_{EM}, and the Poynting vector, $\vec{S}$, inside the gap. (Assume that the current remains constant by adjusting the external potential that causes the current to flow, in order to offset the charging of the capacitor.)

Problem 2

Two concentric conducting spherical shells have radii a and b, respectively. The inner shell has a total electric charge $+Q$ and the outer sphere has a total electric charge $-Q$.

a) Find the electric field in the three regions: $r < a$, $a < r < b$, and $r > b$.

b) Calculate the capacitance of this system.

c) Find the potential energy stored in this capacitor.

Problem 3

Consider the square surface defined by the corners $(1, 1, 1)$, $(1, -1, 1)$, $(-1, 1, 1)$ and $(-1, -1, 1)$. Let there be a point charge q at the origin. Give the electric flux through the square.
Hint: This can be done without calculating any integrals.