5. (a) Define the electric current I through a surface A. Define the symbols involved. [2]

(b) Define the current density $\underline{J}$ in terms of the drift velocity of the carriers, the charge of the carriers, and the number of charge carriers per unit volume. [2]

(c) Write down an expression relating the electric current I and the current density $\underline{J}$. [2]

(d) Write down Ohm's law, relating the current density and the electric field. [2]

6. (a) Write down an expression for the Lorentz force on a charge q moving at velocity $\underline{v}$. [2]

(b) State Gauss's law for magnetism in differential form. [2]

(c) Write down Faraday's law in integral form. [2]

SECTION B

7. (a) A sphere of radius R_1 has a charge $+Q$ uniformly distributed throughout its volume. Surrounding the sphere and concentric with it is a thin spherical shell of radius R_2 which carries a charge $-Q$ uniformly distributed over its surface. Using Gauss' law, determine the electric field as a function of the distance r from the centre of the spheres in the following three cases:

i. $r < R_1$ [4]

ii. $R_1 < r < R_2$ [4]

iii. $R_2 < r$ [4]

(b) Determine the electrostatic energy U of a thin spherical shell of radius R which carries a charge Q uniformly distributed over its surface [*Hint: imagine to assemble the spherical shell by superimposing shells of radius R and infinitesimal charge* dq.]. [8]

8. (a) Explain what is meant by "capacitor", and define the capacitance of a capacitor. [4]

(b) Consider a charged spherical capacitor, consisting of two spherical conducting shells with diameters a, b ($a < b$) and charges $+Q$ and $-Q$ respectively.

i. Determine the electric potential everywhere in the space between the two "plates". [3]

ii. Determine the capacitance C of the spherical capacitor. [4]

iii. Determine the electric field everywhere in the space between the two "plates", and the associated energy density. [4]

iv. Either by direct integration of the energy density of the electric field, or otherwise, determine the total energy stored in the capacitor. [5]