9. (a) Write down the Biot-Savart law. [3]

(b) Write down an expression for the energy density of a magnetic field. [3]

(c) By using Ampère's law, determine the magnetic field outside an infinitely long straight wire carrying a current I. [6]

(d) A thin disc, of radius R, is uniformly charged, with surface charge density σ. The disc rotates around its axis, perpendicular to the disc through its centre, at the angular velocity ω. Determine the magnetic field B at its centre. [*Hint: Consider first the case of a rotating ring of charge, and use the fact that the magnetic field at a centre of a loop of conducting wire carrying a current I is:* $B = \mu_0 I/2R$]. [8]

10. (a) Sketch the magnetic field lines for:

i. a bar magnet [2]

ii. a loop of current [2]

iii. a solenoid of finite length [2]

iv. a toroid [2]

(b) Are the magnetic field lines always closed? (Equivalently: are there points in space which are sources or sinks for the magnetic field lines)? Explain. [4]

(c) Consider a circular flat loop of wire, of area S, rotating at the angular velocity ω around a diameter. A uniform magnetic field $\underline{B}$ is applied. The magnetic field is perpendicular to the axis of rotation of the loop, and has a time-dependence of the form $B = B_0 \sin \omega t$. Assuming that at $t = 0$ the plane of the loop is perpendicular to the applied magnetic field, determine the EMF induced in the loop. [8]

11. (a) Explain what is meant by "electric dipole". [2]

(b) Define the electric dipole moment. [2]

(c) Determine the total force on an electric dipole in a uniform electric field $\underline{E}$. [4]

(d) Write an expression for the torque on a dipole in a uniform electric field $\underline{E}$. [2]

(e) Define the magnetic dipole moment of a loop of current. [2]

(f) A particle of charge q is rotating in a circular orbit of radius r with angular velocity ω. Determine the magnetic moment associated with the motion of the charge. [8]

END OF PAPER