Y2 Electromagnetism 2

Non-assessed problem sheet 3 (weeks 5–6)

Magnetic field in materials

UNIVERSITY OF BIRMINGHAM
School of Physics and Astronomy

1) Consider an infinitely large plate of finite thickness, with a uniform magnetisation $\vec{M}$, placed in vacuum. Find the magnitudes of the $\vec{B}$ and $\vec{H}$ fields inside and outside the plate in two cases: 1) $\vec{M}$ is perpendicular to the plate; 2) $\vec{M}$ is parallel to the plate.

2) Consider a toroidal electromagnet with a steel core of length $L = 1.4$ m, and a gap width $h = 1$ cm. How many turns of wire carrying a current of $I = 3$ A are required to create a magnetic field of $B = 1$ T in the gap? Assume the relative permeability of steel to be $\mu = 10^3$.

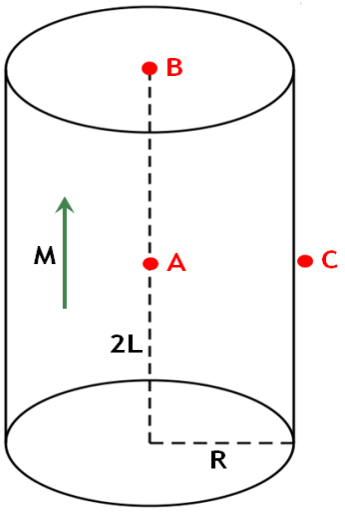
3) Consider an infinitely long solenoid with a surface current perpendicular to its axis. Prove that the magnetic field $\vec{B}$ at any point inside the solenoid is parallel to its axis and that $B = \mu_0 i$, where i is the surface current density.

4*) Prove that at any point inside a solenoid of a finite length, with a surface current perpendicular to its axis of density i, the component of the magnetic field parallel to the axis of the solenoid is

$$B_z = \mu_0 i \frac{\Omega}{4\pi},$$

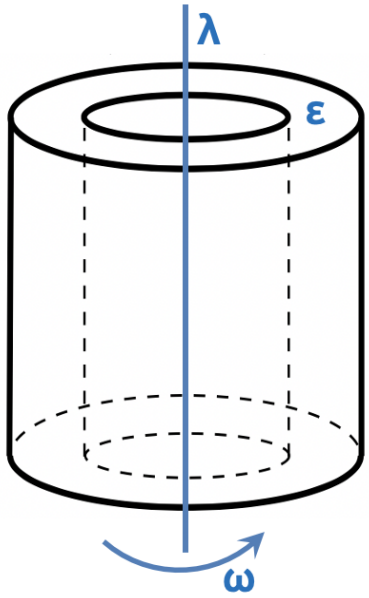
where Ω is the solid angle subtended by the solenoid from that point.

5) Consider a cylindrical permanent magnet of radius R and length $2L$ (such that $R \ll L$), with a uniform magnetisation $\vec{M}$ perpendicular to the base, placed in vacuum. Find the direction and magnitude of the magnetic field $\vec{B}$: A) at the centre of the magnet; B) at the centre of the base; C) just outside the magnet in the plane of symmetry parallel to the bases.



6) Consider a right circular cylinder of radius R and length L, made of ferromagnetic material with relative permeability μ. The cylinder is located in vacuum, in a uniform external magnetic field $\vec{B}_0$ perpendicular to its base surface. Find the magnetic field $\vec{B}$ in the cylinder in two cases: 1) $R \ll L$; 2) $R \gg L$. Explain the dependence of the result on the shape of the cylinder.

7) Consider a long hollow circular cylinder made of a dielectric material with relative permittivity ε, rotating about its axis of symmetry with an angular frequency ω. A thin wire with a linear density of electric charge λ is located on the axis of symmetry. Find the magnetic field in each point of space.



8) Consider a circular parallel-plate capacitor with a distance L between the plates, filled with a dielectric material of relative permittivity ε and relative permeability μ. A variable voltage $V(t) = V_0 \sin(\omega t)$ is applied between the plates. Neglecting edge effects, find the magnetic field $\vec{B}(r, t)$ in the capacitor, where r is the distance to the axis of symmetry.