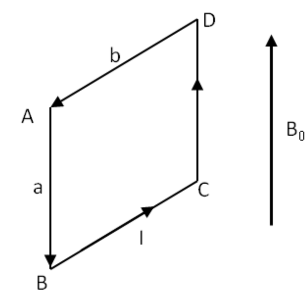
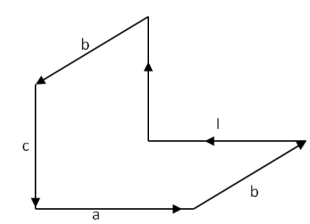
9.7 PROBLEMS

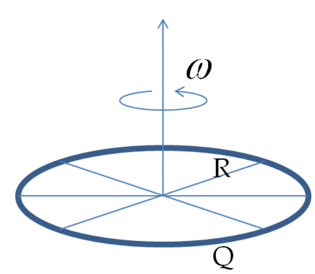
Problem 9.7.1. A rectangular wire carries a current I and lies in a uniform magnetic field as shown in the figure. Find (a) the magnetic dipole moment of the loop of current, (b) torque on loop of current using force on dipole formula, and (c) energy it will take to flip the direction of the magnetic dipole by 180°. (d) Draw the orientation of the loop when the magnetic dipole is flipped by 180°.



Problem 9.7.2. (a) Find the direction and magnitude of magnetic dipole moment of a closed loop of current shown in the figure. (b) There is a uniform magnetic field of magnitude B_0 pointed vertically upward in the region of the loop. Find magnitude and direction of torque on the loop. (c) What is the amount of potential energy of the dipole in the present orientation? Ans: (b) Magnitude $IbcB_0$, (c) $-IbcB_0$.



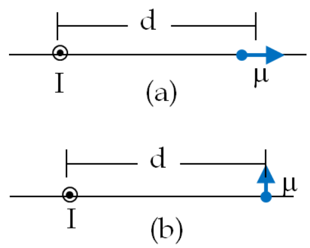
Problem 9.7.3. A thin ring of radius R has an excess charge Q on it. The ring is rotated about an axis through the center of the ring and perpendicular to its plane at a uniform angular speed ω. (a) Find the magnitude and direction of the magnetic dipole moment. (b) What is the magnitude and direction of the magnetic field on a point on the axis far away from the ring such that the distance z of the point from the center of the ring is such that $|z| >> R$. Ans: (a) Magnitude $\omega Q R^2/2$ (b) Magnitude $\mu_0 \omega Q R^4/4z^3$.



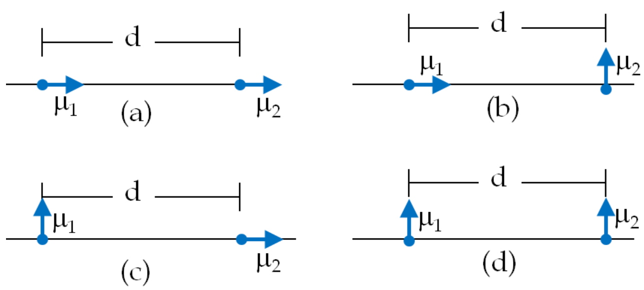
Problem 9.7.4. A non-conducting rod of length L has a uniform charge density Q/L distributed on it. The rod is then pivoted on one end and rotated at a uniform angular speed ω. Show that the rod will have magnetic dipole moment of magnitude $\frac{1}{6}\,\omega\, Q\, L^2$. Draw a figure and state the direction of the magnetic dipole moment vector.

Problem 9.7.5. A sphere of radius R carries a charge Q uniformly distributed on its surface. The sphere rotates about an axis through its center at an angular speed of ω. (a) Find the magnitude and direction of magnetic dipole moment. (b) Find the magnitude and direction of magnetic field on the axis at a far away point P. (c) Let z be the axis of rotation, then what is the magnitude and direction of magnetic field at a far away point on the xy-plane?

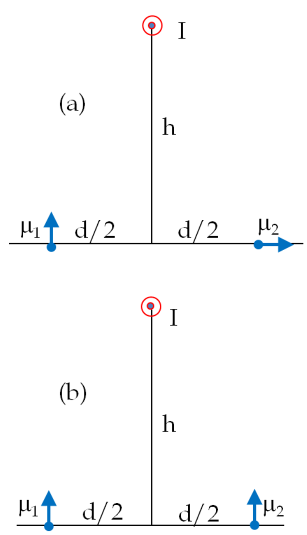
Problem 9.7.6. Find the force on a dipole $\vec{\mu}$ from a current I in a long straight wire in each of the cases shown in the figure.



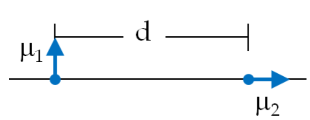
Problem 9.7.7. Find the force on dipole $\vec{\mu}_2$ from $\vec{\mu}_1$.



Problem 9.7.8. Refer to the figure to the right where magnetic dipoles are fixed in their positions. Find the force per unit length on the current carrying wire on a small section of a long wire passing through the plane.



Problem 9.7.9. Find the work done in bringing two dipoles from infinity and rotating them to the following orientation.



Problem 9.7.10. A solenoid with 10 turns per cm and carrying a 0.1 A current has a 4 cm long and 1 cm diameter copper cylinder inside it. Determine the magnitude and direction of magnetization of the copper cylinder? Ans: Magnitude 0.97×10^{-3} A/m, Direction opposite to the magnetic field.

Problem 9.7.11. A small piece of silver of mass 100 mg is brought close to the north pole of a magnet that has a net magnetic field 3 T and a gradient of 20 T/m at the site of the sample. Find the magnitude and direction of the force on copper due to its diamagnetism. Hint: First estimate the induced magnetic dipole moment and then calculate the force on it.

Problem 9.7.12. Nuclear magnetic resonance (NMR) uses magnetic moments of spins of nuclei. For instance consider water molecule. Its electrons all have their spins paired up as a result water is a diamagnetic material. But the protons of the two hydrogen atoms each with nuclear spin magnetic moments of magnitude 2.79 μ_N each are free to orient in space and act as permanent dipoles. A magnetic field of 3 T is applied on a 100 gram water sample. (a) Find the direction and magnitude of the magnetic dipole moment due to alignment of nuclear magnetic dipoles. (b) How much energy will it take to flip 10% of the aligned dipoles by 180°? Ans: (a) Magnitude: 5.89×10^{-2} A.m^2, (b) 3.53×10^{-2} J.

Problem 9.7.13. Ten magnetic particles stick together and form a string such that the magnetization is uniform with magnitude $8 \times 10^5 A/m$. Each particle is cylindrically shaped with radius 10 μm and length 90 μm. If the string makes is aligned to earth's local magnetic field of magnitude $0.5 \times 10^{-4} T$. Find energy needed to rotate the particles so that they face an angle 30° to the external field.

Problem 9.7.14. What is the magnetic field $\vec{B}$ inside a solenoid of 30 turns/cm carrying current 2 A if inside space is filled with (a) tungsten, (b) lead?

Problem 9.7.15. A magnet shaped as a thin cylinder can be thought of as a collection of dipoles. Consider a uniformly magnetized thin bar of radius of cross-section a and length L having a uniform magnetization of magnitude M parallel to its length. Find the magnitude and direction of magnetic field at a point along the axis of the cylinder. Ans: Magnitude: $\frac{\mu_0 M}{\pi}\left[\frac{1}{(2h-L)^2} - \frac{1}{(2h+L)^2}\right]$.

Problem 9.7.16. A magnet shaped as a thin disk can be thought of made up of dipoles. Consider a uniformly magnetized thin disk radius R having a uniform magnetization of magnitude M perpendicular to its surface. Find (a) the magnitude and direction of the equivalent current around the rim, and (b) the magnetic field from the magnet at a point on the axis. Ans: (a) Magnitude: M, (b) Magnitude: $\mu_0 M R^2/2(z^2 + R^2)^{3/2}$.