Magnetic Fields of Currents

Basic Problems

1. A long, straight wire carries a current with magnitude 10 A. Calculate the magnitude of the magnetic field at distances 10 cm, 40 cm and 4 m.
2. A long, straight wire runs perpendicularly towards the earth's surface in Zurich. It carries a current of 13 A. Where does its field compensate the horizontal component of the earth's magnetic field?
3. Suppose there was a wire around the earth's equator carrying a current of 15 A. What would be the magnitude of the resulting magnetic field at the centre of the earth?
4. A piece of wire can be bent into either a circular loop or a square. Calculate the ratio of the resulting magnetic fields' magnitudes at their respective centres.
5. The magnitude of the magnetic field inside a 25 cm long solenoid carrying 1.5 A of current is measured to be 2.2 mT. Calculate the coil's number of turns.
6. A helical spring carrying a constant current is extended by 20 %. How does this influence the magnetic field inside the spring?
7. Two copper wires with the same length are used to make two solenoids of equal length. The ratio of the solenoids' radii is 2 : 1. When the same current is flowing through the coils, what is the ratio of the respective magnetic fields inside the solenoids?
8. A coil is 12 cm long and has a radius of 4.5 cm. What is the percentage error you make when calculating the magnitude of the magnetic field using the solenoid approximation?
9. A *ferrofluid* is a liquid which becomes strongly magnetised when placed in a magnetic field. For a ferrofluid in the field of a solenoid with 15 turns/cm carrying a current of 370 mA the field within the fluid is measured to be 890 mT. Calculate the fluid's magnetic permeability.
10. When placed in an inhomogeneous magnetic field, paramagnetic and diamagnetic materials experience forces in opposite directions. Explain this phenomenon.

Additional Problems

11. Two straight with a mutual distance $2 \cdot r$ run perpendicularly to each other. Both carry a current of magnitude I. Determine direction and magnitude of the magnetic field at the centre of the shortest distance between the two wires.
12. Two straight parallel wires are placed at a distance of 12 cm. They carry the currents 15 A and 25 A, respectively (opposite directions). Calculate the magnitude of the magnetic field at a point in the plane defined by the wires which
    a) has the same distance to both wires;
    b) has distance 3 cm from the first and 9 cm from the second wire.
    c) Find the points in the plane where the magnetic field vanishes.
13. A compass needle is placed in a solenoid which is oriented in east-west direction. The coil is 60 cm long and has 340 turns. At a current of 31 mA the compass needle is deflected by 55° from its initial direction. Calculate the horizontal component of the earth's magnetic field.
14. A family living close to a railway line is worried about the magnetic field produced by the huge currents (typically 100 A) flowing through the overhead contact line. The distance between the tracks and their living room is some 10 m.
    a) Estimate the magnitude of the magnetic field in the living room. Compare the result to a typical value of the earth's magnetic field and to the *DIN limit for low-frequency magnetic fields*, which is $B_{max} = 0.4$ mT.
    b) The tracks are used as the return line for the current. How does this affect the magnetic field in the living room?

Solutions: 1. 20 µT/5 µT/0.5 µT; 2. 12 cm to the east; 3. 1.5 pT; 4.16 : π^2; 5. 292; 6. -17%; 7. 1 : 2; 8. 25 %; 9. 1280; 12. 130 µT, 160 µT, 4.5 cm from greater current; 13. 22.1 µT; 14. 2 µT.