CHAPTER 28
SOURCES OF MAGNETIC FIELD

Discussion Questions

Q28.1 It would be analogous to a point charge. Magnetic field lines would terminate on it. The magnetic flux through a closed surface would be proportional to the net number of magnetic monopoles in the volume enclosed by the surface.

Q28.2 The moving charges produce their own magnetic field. The net field is then the vector sum of the field of the moving charges and the earth's field.

Q28.3 The wire can be considered infinitely long when calculating the magnetic field at points whose distance from the wire is much less than their distance from either end of the wire.

Q28.4 The energy comes from the electrical energy of the currents, which in turn comes from the emf that drives the current through the conductors. There is no contradiction. The magnetic force is perpendicular to the direction of the drift velocity of the current-carrying electrons in the conductors so doesn't affect the magnitude of the drift velocity. The motion of the wires is perpendicular to the motion of the current-carrying charges in the wires. It is the motion of the wires, in the direction of the magnetic force, that causes work to be done by this force.

Q28.5 The wires carrying currents in opposite directions produce magnetic fields that cancel because they are in opposite directions.

Q28.6 Currents in the same direction attract and currents in opposite directions repel. If all three wires carry currents in the same direction they will all three attract each other. There is no way to have all pairs with opposite currents, so it is not possible to have all three wires repel each other.

Q28.7 The force on a conductor is due to the magnetic field of the other conductor. The field of a conductor doesn't exert a force on the conductor that produces the field. The forces between conductors are due to the magnetic force between the moving charges in one conductor and the moving charges in the other conductor.

Q28.8 The two loops attract each other. The magnetic force on the inner loop is radially outward and the magnetic force on the outer loop is radially inward.

Q28.9 Adjacent turns of wire carry currents in the same direction and therefore attract each other.

Q28.10 The Biot-Savart law applies directly to an infinitesimal current element. In a practical calculation for an actual current configuration an integral must be done. The difficulty of applying the Biot-Savart law depends on the difficulty of performing that integral for the particular current configuration. When you us the Biot-Savart law you solve directly for $\vec{\boldsymbol{B}}$ at a point. Ampere's law relates a line integral around a closed path to the total current enclosed by the path. Ampere's law is easiest to apply when a path can be chosen for which $\vec{\boldsymbol{B}}$ is tangent to the path and constant at all points on the path. Ampere's law involves $\vec{\boldsymbol{B}}$ at many points simultaneously. This is an advantage for calculating B when B is the same at all these points.

Q28.11 For a toroidal solenoid the space inside the solenoid closes on itself so the field lines can stay inside the solenoid and still close on themselves. Field lines for a straight solenoid must leave the interior of the solenoid to close on themselves.

Q28.12 (a) No. Between the two wires the fields of the wires are in the same direction so they don't cancel. Above both wires or below both wires the two fields are in opposite directions, but all points in these regions are closer to one wire than to the other. Therefore, the two magnetic fields can't have the same magnitude and can't completely cancel even though they are in opposite directions. (b) Yes. Between the two wires the fields of the wires are in opposite directions. At a point midway between the two wires, the same distance from each wire, the magnitudes of the two fields are equal so they cancel completely.

Q28.13 Two parallel conductors carrying current in the same direction attract each other. So, the current in *L* must be from right to left and this requires *b* to be the positive terminal of the battery.

Q28.14 At the center of the ring $B_0 = \dfrac{\mu_0 I}{2a}$. On the axis of the ring at a distance *x* from the center of the ring, $B = \dfrac{\mu_0 I a^2}{2\left(x^2 + a\right)^{3/2}}$. If *a* is doubled, the field at the center of the ring is halved. The field at *P* changes by a different factor. For example, if *x* is much larger than *a* then $B = \dfrac{\mu_0 I a^2}{2x^3}$ and *B* increases by a factor of four when *a* is doubled.

Q28.15 Since $F = IlB\sin\phi$, $1\ \text{N} = 1\ \text{A}\cdot\text{m}\cdot\text{T}$. $1\ \text{N}\cdot\text{m} = 1\ \text{A}\cdot\text{m}^2\cdot\text{T}$. $1\ \text{N}\cdot\text{m} = 1\ \text{J}$ so $1\ \text{J} = 1\ \text{A}\cdot\text{m}^2\cdot\text{T}$ and $1\ \text{J/T} = 1\ \text{A}\cdot\text{m}^2$.

Q28.16 Smaller permeability means it is more difficult for an external magnetic field to align the atomic magnetic moments of the material. The tendency of the atomic magnetic moments to align themselves parallel to the magnetic field is opposed by their random thermal motion, and the energy of this motion increases with increasing temperature.

Q28.17 The magnetic susceptibility of liquid oxygen must be larger than that of liquid nitrogen. The magnet does attract oxygen gas to its poles but the force is too small to affect the random motion of the molecules associated with their temperature.

Q28.18 If each atom has a net magnetic moment then the material is paramagnetic. If the net magnetic moment of each atom is zero in the absence of an external field, but if an external field can induce a net magnetic moment, then the material is diamagnetic.

Q28.19 Paramagnetism is due to partial alignment of the magnetic moments of individual atoms and this alignment is disrupted by the random motion of the atoms, motion that increases when the temperature increases. Diamagnetic susceptibility depends on how easy it is to induce a net magnetic moment in an atom that has no magnetic moment in the absence of the external field. This effect is independent of the initial orientation of the atom so is not affected much by temperature.

Q28.20 The effect is based on conservation of angular momentum. As shown in Fig.28.24, the atomic magnetic moment is directed opposite to the atomic angular momentum. So, when the cylinder is magnetized and the atomic magnetic moments are partially aligned to produce a net magnetic moment, the atomic angular momenta are also aligned and produce a net angular momentum of the cylinder. This angular momentum is due to motion at the atomic level and not to rotation of the cylinder. But when the cylinder's magnetic moment reverses direction this net atomic angular momentum also reverses direction and by conservation of angular momentum the cylinder must rotate so its rotational angular momentum will keep the total angular momentum constant.