

PHY 2005 Applied Physics 2 - Summer 2011
Solutions for Suggested Homework Problems (Chapter 22)

2. The magnetic force on a wire of length L carrying current I in a uniform magnetic field B is $F = IBL\sin\theta$, where θ is the angle between the direction of the magnetic field and that of the current. The direction of the force is given by the right hand rule. a) $F = IBL\sin 90^\circ = 0.360 \text{ N}$, into the page b) $F = IBL\sin 50^\circ = 0.276 \text{ N}$, into the page c) $F = IBL\sin 0^\circ = 0$. Note $150 \text{ G} = 0.015 \text{ T}$ and $60 \text{ cm} = 0.6 \text{ m}$.

5. The component of the field perpendicular to a current causes the magnetic force; this is because $B\sin\theta = B_\perp$. The force on the vertical wire is $F = IB_xL = 10.2 \times 10^{-4} \text{ N}$, where B_x is the horizontal component of the field. The right hand rule tells you that the force is directed to the west.

10. The magnetic force on charge q moving with a speed v in a magnetic field B is $F = qvB\sin\theta$, where θ is the angle between the direction of the field and that of the velocity. a) A negative charge moving in one direction is equivalent to a positive charge with the same magnitude moving in the opposite direction. So point your thumb in the direction *opposite* the velocity of the electron. The magnetic force is directed out of the page. The magnitude is $F = evB\sin 20^\circ = 5.75 \times 10^{-15} \text{ N}$ b) The right hand rule tells you that the force is directed into the page. The magnitude of the force is the same as that on the electron because they have the same amount of charge: $F = evB\sin 20^\circ = 5.75 \times 10^{-15} \text{ N}$

12. When the beryllium ion is moving along $+x$ axis, the magnetic force is $+y$ direction. Therefore, the ion follows a circular path above x axis. The radius of the circle is $R = mv/(qB) = 1.28 \text{ m}$.

16. The component parallel to the field and that perpendicular field are $v_\parallel = v\cos 25^\circ = 4.53 \times 10^6 \text{ m/s}$ and $v_\perp = v\sin 25^\circ = 2.11 \times 10^6 \text{ m/s}$, respectively. The force on the proton is in the yz -plane and proportional to $v\sin\theta = v_\perp$. Therefore, the proton takes a circular motion in the yz -plane of radius $R = mv_\perp/(qB)$ while moving in the $+x$ direction with a velocity v_\parallel . The resultant path is a helix. The radius of the helix (precisely speaking, the radius of the circle in the yz -plane) is $R = mv_\perp/(qB) = 4.40 \times 10^{-2} \text{ m}$. The pitch of a helix is the distance between adjacent turns, which is given by $p = v_\parallel T = 2\pi R (v_\parallel/v_\perp) = 0.594 \text{ m}$

20. A current carrying straight wire produces a magnetic field with magnitude $B = \mu_0 I / 2\pi r$ at a position distance r away from the wire. a) The separation distance is $5 \text{ cm} = 0.05 \text{ m}$. The field strength is $B = \mu_0 I / 2\pi r = 8.0 \times 10^{-5} \text{ T}$. b) Recall the magnetic force on a current in a field is $F = B_\perp LI$. The field due to one of the wires is perpendicular to the current in the other. Therefore, force per unit length is $F/L = BI = \mu_0 I^2 / 2\pi d = 16 \times 10^{-3} \text{ N}$. The right hand rule tells you that the force is attractive.

21. a) The magnetic fields due to two currents are equal in magnitude but opposite in direction at a point midway between the two currents. Thus the net field is zero. b) The fields due to two currents are in the same direction. Therefore, the net field is $B = 2 \times \mu_0 I / [2\pi(d/2)] = 3.2 \times 10^{-4} \text{ T}$.

23. An N -turn flat coil generates a magnetic field with strength $B = N \mu_0 I / 2a$. Solving the equation for I , we obtain $I = 2aB / N\mu_0 = 2.39 \text{ A}$

24. The magnetic field due to a solenoid is given by $B = \mu_0 nI$, where n is the number of turns per unit length. Our n is $5000/0.4 = 12500 \text{ turns/m}$. With given values, the expression for B yields $B = \mu_0 nI = 3.14 \times 10^{-2} \text{ T}$

29. a) The direction of the magnetic moment can be determined as follows: Curl your fingers in the direction of the current. Then your extended thumb points in the direction of the

magnetic moment. Since the magnetic moment tries to align with the magnetic field, the coil turns counterclockwise. b) The angle between the field and the magnetic moment is 60° . Therefore, the torque on the loop is $\tau = MB\sin 60^\circ = (NIA)B\sin 60^\circ = 7.79 \times 10^{-2} \text{ N}\cdot\text{m}$.

33. The meter movement deflects full scale for a current of $I_M = \Delta V/R_M = 2.5 \times 10^{-5} \text{ A}$. Therefore, when a current of 1.5 A flows in the ammeter, $I - I_M = 1.5 - 2.5 \times 10^{-5} \text{ A}$ must flow in the shunt resistor. The voltage across the shunt resistor is the same as that across the meter movement. Thus we have $R_s = \Delta V/(I - I_M) = 1.34 \times 10^{-3} \Omega$.

34. To make a voltmeter, we need to connect a meter movement with a resistor in series. When the voltage across the voltmeter is $\Delta V = 10 \text{ V}$, the potential across the meter movement has to be $\Delta V_M = 2 \times 10^{-3} \text{ V}$ and thus the current flows in the voltmeter is $I = \Delta V_M/R_M = 2.5 \times 10^{-5} \text{ A}$. Since the movement R_M and resistor R_x are connected in series, the total potential drop across the voltmeter is $\Delta V = (R_M + R_x)I$. We solve this equation for R_x to obtain $R_x = \Delta V/I - R_M = 3.9992 \times 10^5 \Omega$.

36. When the range is set at $\Delta V = 25 \text{ V}$, the meter movement R and resistor R_1 are connected in series. Combining the two resistors and applying Ohm's law, we get $\Delta V = (R + R_1)I \Rightarrow R_1 = \Delta V/I - R = 3.836 \times 10^4 \Omega$. If you set the range at $\Delta V' = 150 \text{ V}$, then the meter movement R , resistor R_1 and resistor R_2 are connected in series. We combine the resistors and apply Ohm's law again to obtain $\Delta V' = (R + R_1 + R_2)I \Rightarrow R_2 = \Delta V'/I - R - R_1 = 1.923 \times 10^5 \Omega$.

38. By definition, if you insert a core with relative permeability k_m into a solenoid, the magnetic field in the solenoid gets k_m times stronger than that in the solenoid without the core. Therefore, the relative permeability is $k_m = 0.24/(6 \times 10^{-4}) = 400$.

41. Magnetic field due to a current-carrying long straight wire is inversely proportional to the perpendicular distance from the wire. Let the perpendicular distance from the current to the point where the field strength is 4 T be R . Then the perpendicular distance from the wire to the position where the field is 3 T is $R + 0.5$. We take the ratio of the two magnetic fields to obtain $3/4 = R/(R + 0.5) \Rightarrow R = 1.5 \text{ m}$. The field strength around a straight wire is given by $B = \mu_0 I/(2\pi r)$. We solve this equation for I to obtain $I = 2\pi RB/\mu_0 = 3 \times 10^7 \text{ A}$.

43. At our point of interest, the magnetic field due to the current in Wire #1 is pointed downward and that due to the current in Wire #2 is upward. Therefore, the magnitude of the magnetic field is $|B_1 - B_2| = \mu_0 I/(2\pi r_1) - \mu_0 I/(2\pi r_2) = 8.46 \times 10^{-4} \text{ T}$. Since B_1 is larger than B_2 , the net magnetic field is directed downward.