Part I

1. A straight horizontal wire carries a conventional current of 5.0 A from west to east in a region where there is a magnetic field of 2.0 directed vertically down into the earth. The force per unit length on the wire is

   (a) 2.5 N directed south

   (b) 10 N directed north

   (c) 10 N directed south

   (d) 10 N directed vertically into the earth.

   Answer (b)

2. An alpha particle has four time the mass and twice the charge of a proton. Both particles move perpendicular to a uniform magnetic field with the same speed. The ratio of the magnetic force on the proton to the magnetic force on the alpha particle is

   (a) 1:1

   (b) 1:2

   (c) 2:1

   (d) 1:4

   Answer (b).

3. A charged particle enters a uniform magnetic field. If the angle between the velocity and field is not 90^0 the path of the particle will be

   (a) circular.

   (b) elliptical.

   (c) parabolic.

   (d) helical.

   Answer (d).

4. A current carrying loop in a uniform magnetic field always tends to rotate until the plane of the loop is

   (a) parallel to the field.

   (b) perpendicular to the field.

   (c) at a 45^o angle to the field.

   (d) it will not tend to rotate since the net force is zero.

   Answer (a).

Part II

1. Describe whether or not the following actions can be accomplished with a constant and uniform electric or a magnetic field. Explain your answers, indicating which fields can and which cannot accomplish the action and if your answer is valid for any orientation of the field(s). Must any other condition be satisfied?

   (a) move a charged particle in a circle.

   A uniform magnetic field will move a charged particle in a circle provided it is oriented perpendicular to the velocity of the particle. A uniform electric field cannot move a charged particle in a circle because the direction of the force is always in the same direction. (Note: the field due to a point charge is not uniform and can cause a charge to move in a circle)

   (b) exert a force on a piece of dielectric material.

   Neither field can exert a force on a dielectric material. However, a non-uniform electric field can exert a force on a dielectric material by polarizing it and attracting the closer charge more strongly than it repels the distant charge.

   (c) increase the speed of a charged particle.

   Only the uniform electric field can increase the speed of a charged particle. The magnetic force can change the direction but not the speed.

   (d) accelerate a moving charged particle.

   Both field can accelerate a moving charged particle, but in the case of the magnetic field the charged particle must have a component of velocity perpendicular to the magnetic field.

   (e) exert a force on a charged particle which is initially at rest.

   A magnetic field exerts no force on a particle that is at rest. An electric field can.

2. A proton moves with speed v perpendicular to a uniform vertical magnetic field B and follows a circular path of radius r before leaving the field. Suppose an electron enters the same field with the same speed.

   (a) What differences would you expect to observe in the path that the two particle follow?

   The two particle would travel in a circle in opposite directions – one clockwise and one counterclockwise. Also since the electron is so much less massive it would accelerate more rapidly and would therefore travel in a circle with a much smaller radius.

   (b) In what way should the magnetic field be adjusted so that the electron would follow the same path that the proton did.

   The magnetic field would need to be reduced and changed to the opposite direction.

   (c) Suppose the field strength used for the proton was 0.50 T what should the magnitude of the field used for the electron be?

   $F_{\text{net}} = ma \Rightarrow qvB = \frac{mv^2}{r} \Rightarrow r = \frac{mv}{qB}$.

   Now since $r_{\text{proton}} = r_{\text{electron}}$ then $\frac{m_{\text{electron}} v}{qB_{\text{electron}}} = \frac{m_{\text{proton}} v}{qB_{\text{protron}}}$ where B_{electron} is the value of the magnetic field that is required to accelerate the electron in a path with the same radius as the proton. So $\frac{m_{\text{electron}}}{B_{\text{electron}}} = \frac{m_{\text{proton}}}{B_{\text{protron}}} \Rightarrow B_{\text{electron}} = B_{\text{protron}} \frac{m_{\text{electron}}}{m_{\text{proton}}} = 0.5 \frac{9.1 \times 10^{-31}}{1.67 \times 10^{-27}} =$ 2.7×10^{-4} T. (in the opposite direction)

3. You have a wire of length L from which to make a square coil for a DC motor. You want a DC motor which has a torque which is as large as possible.

   (a) Does the torque of a DC motor increase or decrease with the number of coils?

   With more coils the torque is greater.

   (b) Does the torque of a DC motor increase or decrease with the area of a coil?

   With greater area the torque is greater.

   (c) Given that you have a single piece of wire from which to make the coil for your motor would you be better off making a large coil with one loop or a smaller coil with two loops?

   For a single loop the sides of the square coil would have length $L/4$ so the area would be $(L/4)^2 = L^2/16$. For a double loop the sides of the square coil would be $L/8$ and the area would be $(L/8)^2 = L^2/64$. So the coil with one loop has four times the area as the coil with two loops. Therefore, it would be better to have a single loop with a large coil. (This is contingent on being able to find magnets that can produce a uniform magnetic field through the larger loop.)

   (d) Suppose the length of the wire is $L = 1.00$ m, the current in the wire is $I = 1.7$ A and the magnetic field is 0.34 T find the maximum torque for the one loop coil and the two loop coil and confirm your answer to (c).

   $\tau = NIAB$.

   For one loop $A = L^2/16 = 0.0625\ \text{m}^2$ so $\tau = 1.7 \times 0.0625 \times 0.34 = 0.036$ N·m.

   With two loops $A = L^2/64 = 0.0156\ \text{m}^2$ so $\tau = 2 \times 1.7 \times 0.0156 \times 0.34 = 0.018$ N·m.

   Notice that the torque is half for the two loop coil as predicted in (c).