Part I

1. A long straight vertical wire carries a steady current in the upward direction. At a point due north of the wire, what is the direction of the magnetic field that the wire produces?

   (a) North.

   (b) South.

   (c) East.

   (d) West.

   Answer (d).

2. A rectangular loop is placed in a uniform magnetic field with the plane of the loop perpendicular to the direction of the field. When a current flows through the loop it feels

   (a) a net force but no net torque.

   (b) a net torque but no net force.

   (c) a net force and a net torque.

   (d) neither a net force nor a net torque.

   Answer (d).

3. The force per unit length on two long parallel wires is measured to be 6.0×10^{-5} N/m when they are separated by 2.0 cm. When the two wires are moved to a distance of 1.0 cm and the current in each of the wires is doubled the new force is

   (a) 4.8×10^{-4} N/m

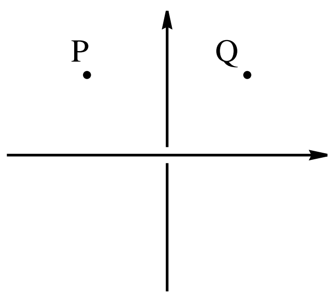
   (b) 3.2×10^{-4} N/m

   (c) 1.2×10^{-4} N/m

   (d) 0.6×10^{-4} N/m

   Answer (a). The force is 8 times as great because each current is doubled and the distance is halved.

4. The diagram on the right shows two current carrying wires which cross but do not touch. At which of the following points is the magnetic field zero.

   (a) At P

   (b) At Q

   (c) At both P and Q

   (d) At neither P nor Q

   Answer (b).

Part II

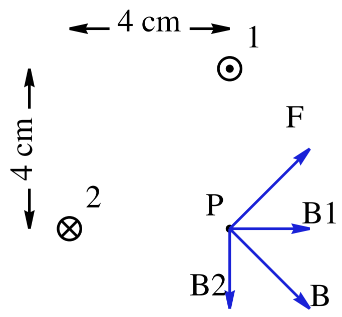
1. (a) It is desired to produce a magnetic field strength of 2.0×10^{-3} T along the axis of a long solenoid. If the solenoid is 0.15 m long and has 200 turns per centimetre, what current in the solenoid will produce this field?

   $B = \mu_0 n I$, where $n = (200 \text{ turns/cm})(100 \text{ cm/m}) = 2 \times 10^4$ turns/m.
   So $I = B/\mu_0 n = 2.0 \times 10^{-3}/(4\pi \times 10^{-7})(2 \times 10^4) = 0.080$ Amps.

   (b) Suppose the solenoid is uncoiled into a long straight wire and carries the same current. At what distance from the wire will the magnetic field strength be the same as it was inside the solenoid in part (a).

   For a long straight wire the field is $B = \frac{\mu_0}{2\pi}\frac{I}{r}$.
   So $r = \frac{\mu_0}{2\pi}\frac{I}{B} = \frac{2 \times 10^{-7}(0.08)}{2.0 \times 10^{-3}} = 8 \times 10^{-6}$ cm. This is an absurdly small distance from the center of the wire. In fact it is likely to be inside the wire, and here the field would be less than predicted.

2. The following diagram shows a cross sectional view of two wires, each carrying a current of 2.0 amps. The current in wire 1 flows our of the page and current of wire 2 flows into the page.



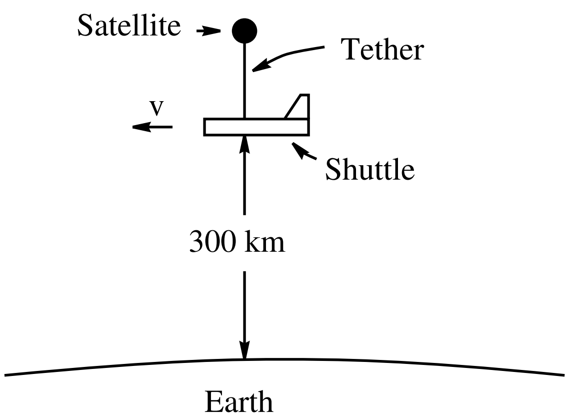
   (a) What is the strength of the force between the two wires? Is it attractive or repulsive?

   $F = \mu_0/2\pi \frac{I_1 I_2}{r} \frac{(2^{-7})(2^2)}{\sqrt{0.04^2 + 0.04^2}} = 1.4 \times 10^{-5}$ N
   Since the currents are opposite they feel a repulsive force.

   (b) At the point marked P indicate the direction of the field due to wire A and wire B and the direction of the total field.

   (c) A wire, c, is place at point P, parallel to the other two wires and with a current flowing out of the page. Draw an arrow indicating the direction of the force on wire C.

3. The Tethered Satellite System was an experiment conducted on the space shuttle in order to create a potential difference to generate electric power. While the shuttle was orbiting 300 km above the equator the astronauts reeled out a satellite attached to the shuttle by a long conducting tether to a position 20 km above the shuttle as shown.



(a) Explain how a potential difference could be generated in this experiment.
The earth has a magnetic field. If the wire is perpendicular to the magnetic field then free electrons will tend to move in the wire setting up an electric field which exerts a force opposite to the magnetic force acting on the electrons

(b) Assuming the diagram above shows a view from the north looking south

(i) indicate the direction of the magnetic field on the diagram.
The field comes out of the page (pointing north).

(ii) indicate the polarity of the induced potential difference between the satellite and the shuttle.
The shuttle will be negatively charged. The satellite will be positively charged.

(c) If the magnetic field in the vicinity of the shuttle was 0.33×10^{-4} Tesla and the shuttle was moving at 7.7 km/s, find the potential difference between the satellite and the shuttle.
Starting from the fact that the Electric and Magnetic forces are equal and opposite $qE = qvB$ and that the potential is $V = EL$, where L is the length of the wire. It follows that $V = vLB = (7.7 \times 10^3)(20 \times 10^3)(0.33 \times 10^{-4}) = 5082$ V.

(d) This potential difference was used to generate a current through the ionosphere. The current was then used to provide power for experiments on the shuttle. What, ultimately would be the source of the consumed energy?
It comes from the gravitational potential energy of the shuttle. The tether carrying a current feels a force due to the magnetic field that it is in. This force acts in the opposite direction to the motion of the shuttle. The shuttle thus loses energy.