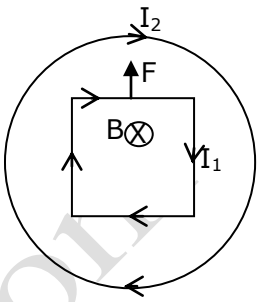
Q- A single-turn square loop of wire of side 2.00 cm, carries a clockwise current of 200 A. The loop is inside a solenoid, with the plane of the loop perpendicular to the magnetic field of the solenoid. The solenoid has 30 turns/cm and carries a clockwise current of 15.0 A Find the force on each side of the loop and the torque acting on the loop.

The magnitude of the magnetic field inside a long current carrying solenoid is given by

$$B = \mu_0 nI$$

Here n is the number of turns per unit length and I is the current in it.

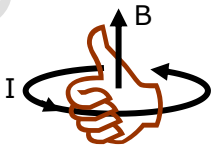


Now n = 30 turns/cm = 3000 turns/m hence the field inside the solenoid will be

$$B = 4\pi*10^{-7}*3000*15 = 5.65*10^{-2}\ T$$

The direction of magnetic field due to a circular current carrying loop is given by the right hand rule, the curled fingers will point the direction of the current in the loop and the stretched thumb will show the direction of magnetic field.

Hence the magnetic field inside the solenoid is into the paper.



Now the force experienced by the current carrying wire in a magnetic field B is given by

$$\vec{F} = I\left(\vec{l} \times \vec{B}\right)$$

The magnitude of the field is given by

$$F = BI\ L \sin\theta$$

Here I is the current in the loop, L is the length of the wire and θ is the angle between the direction of current in the wire and the magnetic field.

As the current in the wire of the square loop is perpendicular to the direction of the magnetic field (parallel to the axis of the solenoid) θ = 90 deg and hence the force on the upper side of the square loop will be

$$F = B*I*L = (5.65*10^{-2}\ T)*(200\ A)*(0.02\ m) = 0.226\ N$$

The direction of the force is given by Fleming's left hand rule that is if the thumb, index finger and the middle finger of the left hand are perpendicular to each other, the index finger is showing the direction of magnetic field, the middle finger is showing the direction of the current in the wire then the force acting on the wire will be in the direction of thumb.

Hence according to this law the force on the upper wire of the square loop will be upward in the plane of the loop, as shown in the figure.

The direction of the current in the lower wire is opposite and hence the force on the lower wire of the loop will be downwards.

The current in the left wire is upward and in the right wire is downward direction. Magnitude of the force on each wire is same 0.226 N.
(The net force on the loop will be zero)

As the pair of forces on opposite sides are parallel, opposite but in the same line of action (no perpendicular distance), the torque on the loop will be zero.

(Considering the current carrying loop as a magnetic dipole, as its magnetic dipole moment is in the direction of external magnetic field, the torque on it will be zero.)