Q- Two long parallel horizontal wires are interacting to each other by a force per unit length of 320 micro-newton/meter when they are separated by a vertical distance of 0.500m. The current in the upper wire is 20.0 A to the right. Determine the location of the line in the plane of the two wires along which the total magnetic field is zero.

Solution:

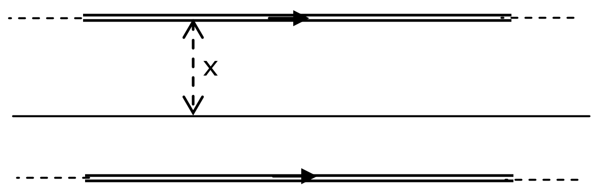
The field between the parallel wires will be zero only if the current in both wires is in same direction and then the force between them is that of attraction.

The force per unit length between two long parallel thin wires carrying current I_1 and I_2 and at a distance d is given by

$$\frac{F}{L} = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{d}$$

Hence the current in the lower wire is given by substituting in above equation as

$$320*10^{-6} = 10^{-7}*\frac{2*20.0*I_2}{0.500}$$

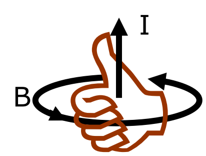


Gives $I_2 = \frac{320*10^{-6}*0.5000}{10^{-7}*2*20.0} = 40$ A

Now the magnitude of magnetic field at a distance ‘a’ due to a long current carrying wire is given by

$$B = \frac{\mu_0 I}{2\pi a}$$

The direction of this field is given by right hand thumb rule, that is holding the wire with right hand in such a way that the stretched thumb is in the direction of current, the direction of the curled fingers will show the direction of magnetic field (or flux) which is circulating the wire.



Hence field due to the wires will have a direction outward from the page above the wire and into the page bellow the wire. So the field will be out of the paper due to both wires above the upper wire and into the paper bellow the lower wire and will be added.

Between the two wires field due to upper wire is into the paper and outward due to the lower wire and hence will be subtracted and here is the possibility for it to be zero.

Let the resultant magnetic field is zero at distance x bellow the upper wire then the magnitude of the field at this distance due to both fields must be equal with opposite direction and hence

$$B = \frac{\mu_0 I_1}{2\pi x} - \frac{\mu_0 I_2}{2\pi(d-x)} = 0$$

Or $\frac{\mu_0 I_1}{2\pi x} = \frac{\mu_0 I_2}{2\pi(d-x)}$

Or $\frac{I_1}{x} = \frac{I_2}{(d-x)}$

Or 20(d - x) = 40x

Gives x = d/3 = 0.500/3 =0.1667 m

Hence the location of all points or the line with zero magnetic field is 0.1667 m bellow the upper wire.

Note:

If the force per unit length is repulsive the direction of the current in the lower wire will be to the left and the field between the wires will be added and hence the zero field area will be above the upper wire (current in the lower is greater) and hence the distance of the line from the lower wire will be d + x and hence the distance will be 0.500 m above the upper wire.