Answer on Question #74424 - Physics – Electromagnetism

Question:

A long, straight wire of radius 5.0 mm carries a current of 20A. i) Calculate the magnetic field at the surface of the wire, and ii) calculate the perpendicular distance, from the axis of the wire, at which the magnitude of magnetic field will be half of its value at the wire surface.

Solution:

We use Ampère's circuital law: the integrated magnetic field around a closed loop

$$\oint\left(\vec{B},\overrightarrow{dl}\right)=\mu_0\, I,$$

where I -- the electric current through the loop, μ_0 ≈1.2566×10^{-6} (N/A^2) -- magnetic constant in vacuum.

i). If the loop is a circle with radius $R_0=5(mm)=5\times10^{-3}(m)$, then $\vec{B}$ will be directed along the loop and $B_0=\left|\vec{B}\right|=const$ on the circle loop. Therefore

$$\oint\left(\vec{B},\overrightarrow{dl}\right)=2\,\pi R_0 B_0,$$

and the magnitude of magnetic field

$$B_0=\frac{\mu_0 I}{2\pi R_0}\approx\frac{1.2566\times10^{-6}\times20}{2\times3.14\times5\times10^{-3}}\approx8\times10^{-4}(T)$$

ii). Due Ampère's circuital law, for a circle loop around the wire, if the radius of the loop R is greater than the radius of the wire R_0, the magnitude of magnetic field is:

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

or

$$R=\frac{\mu_0 I}{2\pi B}=\frac{\mu_0 I}{2\pi B_0}\frac{B_0}{R}=\frac{B_0 R_0}{B}.$$

And if $B=B_0/2$ then

$$R=\frac{B_0 R_0}{B}=\frac{B_0 R_0}{B_0/2}=2R_0=2\times5\times10^{-3}=10^{-2}(m)$$

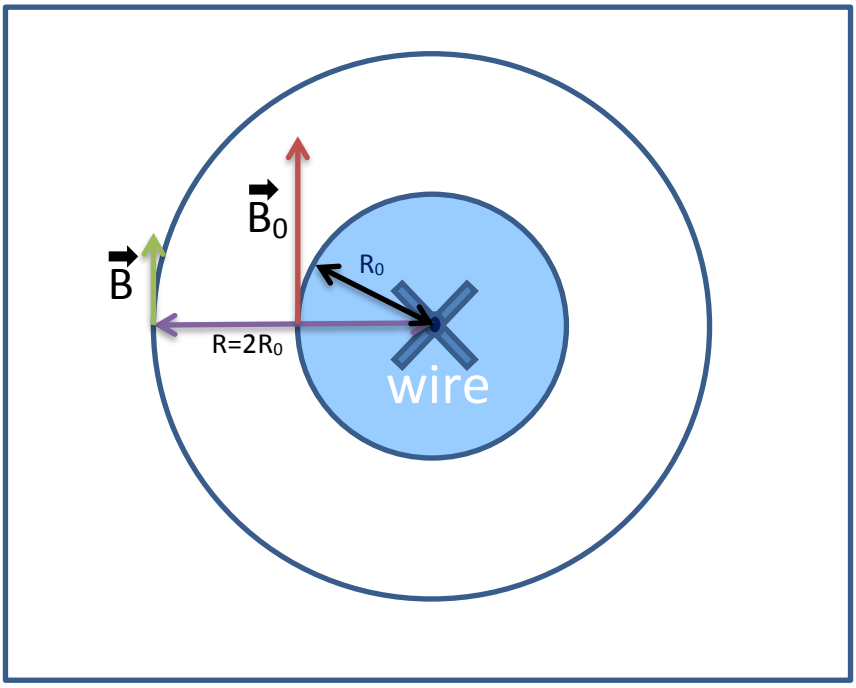

Fig. The wire (blue), the magnetic field at the surface of the wire (red), and the magnitude of magnetic field for the distance $R = 2R_0$ (green).

Answer:

i). the magnetic field at the surface of the wire: $B_0 \approx 8 \times 10^{-4}(T)$

ii). the perpendicular distance from the axis of the wire, at which the magnitude of magnetic field will be half of its value at the wire surface: $R = 10^{-2}(m)$

Comments:

1. Ampère's circuital law – for example:
https://en.wikipedia.org/wiki/Amp%C3%A8re%27s_circuital_law
(the table -- "Forms of the original circuital law written in SI units")

2. we use standard SI units:
T—Tesla, m—metre, N—Newton, A -- Ampere
https://en.wikipedia.org/wiki/International_System_of_Units