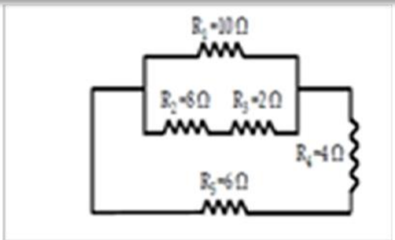
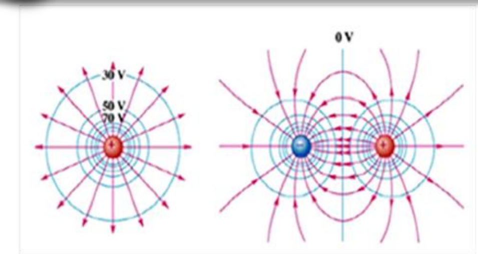
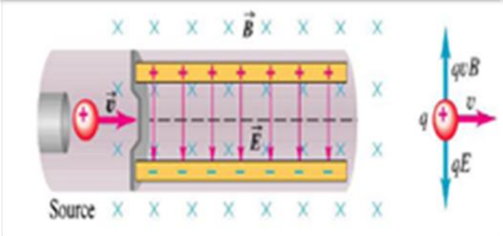
Physics-2







Ch-9

Sources of magnetic fields

يوسـ زويل ـف

Best wishes and good Luck

00966502047005

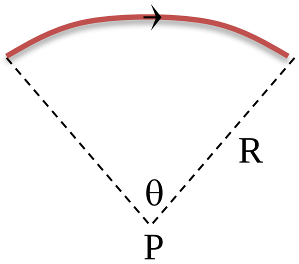
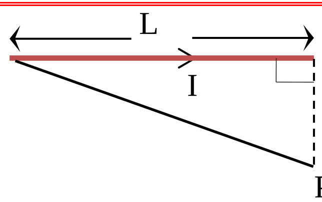
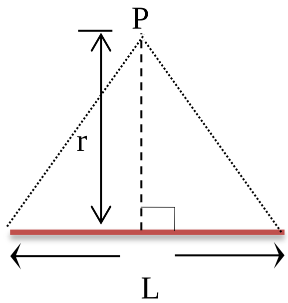
Sources of magnetic fields

شدة المجال المغناطيسي عند نقطة

والناتج عن التيار الكهربي المار في موصل

$d\vec{B} = \frac{\mu_0}{4\pi} \frac{i\, d\vec{s} \times \hat{r}}{r^2}$ Biot–Savart law

$$B = \frac{\mu_0 I}{4\pi} \int \frac{d\vec{s} \times \hat{r}}{r^2}$$

شكل التيار وموضع النقطة	شدة المجال B
(1)  النقطة P على امتداد السلك	$B_p = 0$
قوس دائري زاويته θ P هي المركز 	$B_P = \frac{\mu_0 I}{4\pi R}\,\theta$ ← بالتقدير الدائري $\theta_{\text{دائري}} = \frac{\theta_{\text{بالدرجات}}}{180} \cdot \pi$ $\mu_0 = 4\pi \times 10^{-7}$
 النقطة على العمودي من الطرف	$B_P = \frac{\mu_0 I}{4\pi r} \frac{L}{\sqrt{L^2 + r^2}}$
النقطة على العمودي المنصف للسلك 	$B_P = \frac{\mu_0 I}{2\pi r} \frac{L}{\sqrt{L^2 + 4r^2}}$
	النقطة على العمودي من سلك لانهائي الطول $B_P = \frac{\mu_0 I}{2\pi r}$

تحديد اتجاه المجال باستخدام

قاعدة اليد اليمنى:

نضع اليد اليمنى مفتوحة

عند النقطة بحيث يكون امامها

السلك ويشير الإبهام الى اتجاه

التيار فيكون اتجاه المجال هو

اتجاه بقية الاصابع

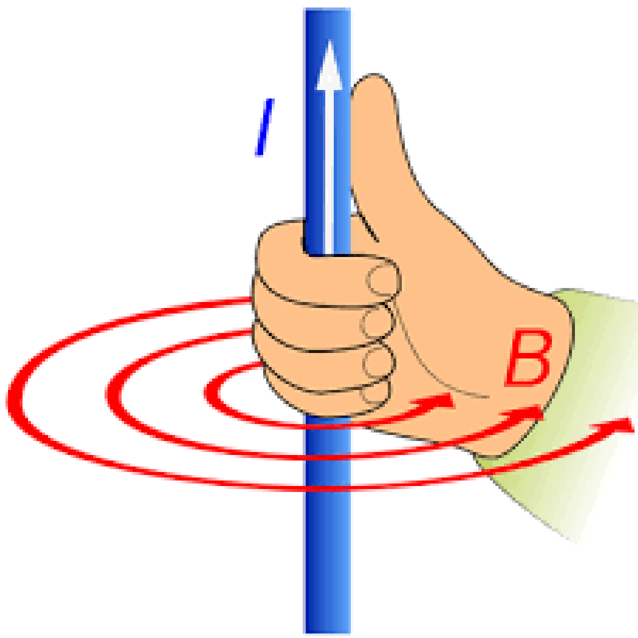
لاتنسى ان

العلامة ⊙ تعني ان المجال عمودي على الصفحة للخارج

Out the paper

العلامة ⊗ تعني ان المجال عمودي على الصفحة للداخل

Into the paper

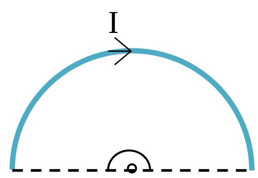


Ex1: A semicircular wire of radius 10 cm carries a current of 1 A.

The magnetic field at the center of curvature is:

(a) 9.9×10^{-8} T (b) 3.15×10^{-8} T (c) 9.9×10^{8} T (d) 3.14×10^{-6} T

Solution



$\theta = 180^\circ$

$= \frac{180}{180} \cdot \pi = \pi$

$I = 1$ A

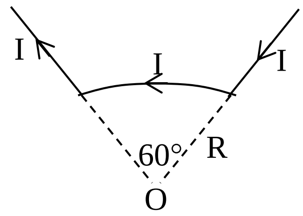
$R = 0.1$ m

$B = \frac{\mu_0 I}{4\pi R} \theta$

$= \frac{4\pi \times 10^{-7} \times I}{4\pi \times 0.1} \cdot \pi$

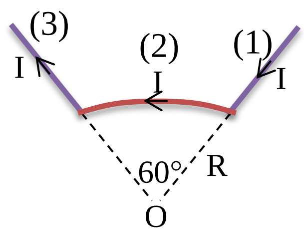
$= 3.14 \times 10^{-6}$ T

Ex2: Calculate the magnetic field at the point O, if I = 10A and R = 10 cm



(a) 1.05×10^{-5} T (b) 3.42×10^{-5} T (c) 3.14×10^{-5} T (d) 6.12×10^{-5} T

Solution



$\theta = \dfrac{\pi}{3}$

I = 10 A

R = 0.1 m

For parts (1) & (3) $\Rightarrow$

B = 0

For part (2)

$$B_2 = \frac{\mu_0 I}{4\pi R}\theta$$

$$= \frac{4\pi \times 10^{-7} \times 10}{4\pi \times 0.1} \cdot \frac{\pi}{3}$$

$$= 1.05 \times 10^{-5} \text{ T}$$

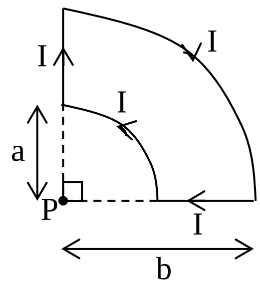
$$B = B_1 + B_2 + B_3 = 1.05 \times 10^{-5} \text{ T}$$

Ex3: What is the magnitude of the magnetic field at point P due to the current carrying wire shown in the figure؟

If $I = 2A$, $a = 20$ cm and $b = 2a$

(a) 2.8 μT (b) 2.8 μT

(c) 0.4 μT (d) 0.8 μT



Solution

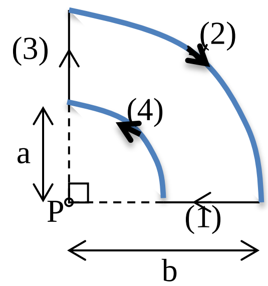
$I = 2$ A

$a = 0.2$ m

$b = 2a$

$= 0.4$ m

For part (1) & (3) ⇒ $B = 0$



For part (2)

$$\theta = \frac{90}{180} \cdot \pi = \frac{\pi}{2}$$

$$B_2 = \frac{\mu_0 I}{4\pi R} \theta$$

$$= \frac{4\pi \times 10^{-7} \times 2}{4\pi \times 0.4} \cdot \frac{\pi}{2}$$

$$T = 7.85 \times 10^{-7} \otimes$$

For part (4)

$$\theta = \frac{\pi}{2}$$

$R = a = 0.2$ m

$$B_4 = \frac{\mu_0 I}{4\pi R} \theta$$

$$= \frac{4\pi \times 10^{-7} \times 2}{4\pi \times 0.2} \cdot \frac{\pi}{2} \odot$$

$$= 1.57 \times 10^{-6} \text{ T} \odot$$

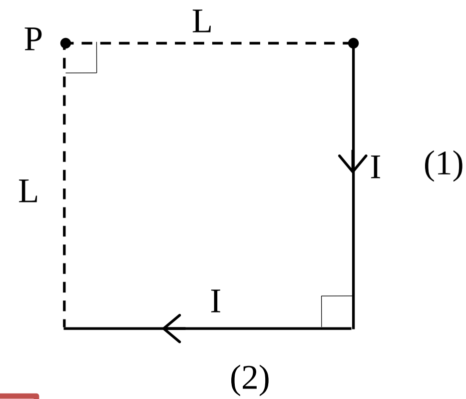
متعاكستان في الاتجاه B_4 ، B_2

$$B_{net} = B_4 - B_2 = 7.85 \times 10^{-7} \text{ T} \cong 0.8 \times 10^{-6} \text{ T} = 0.8 \ \mu\text{T} \odot$$

Ex5: If I = 2A, L = 0.5 m. Find the magnitude of the magnetic field at P.

(a) 2.8 μT (b) 2.8 μT

(c) 0.4 μT (d) 0.8 μT



Solution

I = 2 A

L = 0.5 m

D = 0.5 m

$$B_1 = B_2 = \frac{\mu_0 I}{4\pi r} \frac{L}{\sqrt{L^2 + r^2}}$$

$$= \frac{4\pi \times 10^{-7} \times 2}{4\pi \times 0.5} \cdot \frac{0.5}{\sqrt{(0.5)^2 + (0.5)^2}}$$

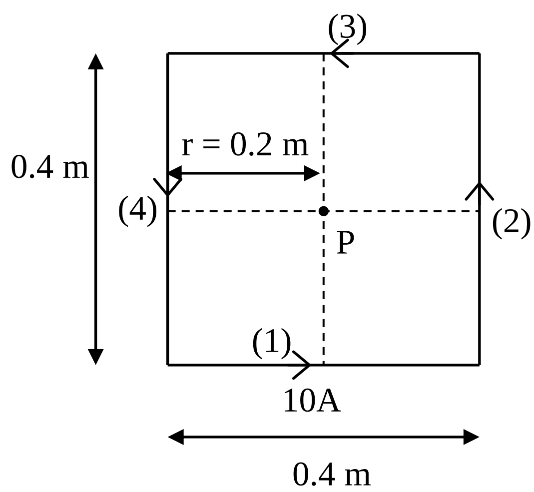
$$= \underline{2.83 \times 10}^{-7} \quad T \quad \otimes$$

$$B_{net} = B_1 + B_2 = \underline{5.66 \times 10}^{-7} \quad T \quad \otimes$$

Ex7: A conductor in the shape of a square of edge length a = 0.4 m carries a current I = 10 A, the magnitude of the magnetic field produced at the center of the square is:

(a) 70 μT (b) 28 μT (c) 7 μT (d) 28 μT (e) 28 T

Solution



$I = 10\ A$

$L = 0.4\ m$

$D = 0.2\ m$

$B_1 = B_2 = B_3 = B_4$

$$= \frac{\mu_0 I}{2\pi r} \frac{L}{\sqrt{L^2 + 4r^2}}$$

$$= \frac{4\pi \times 10^{-7} \times 10}{2\pi \times 0.2} \cdot \frac{0.4}{\sqrt{(0.4)^2 + 4(0.2)^2}}$$

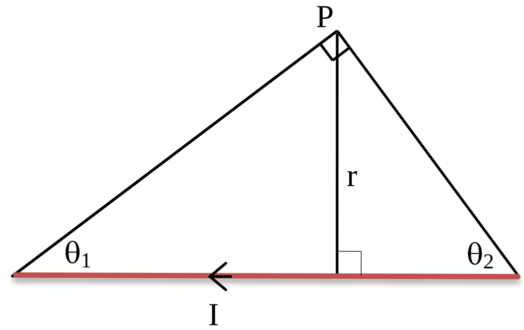
$$= \underline{7.07 \times 10}^{-6} \quad T \odot$$

$$B_{net} = B_1 + B_2 + B_3 + B_4 = \underline{28.28 \times 10}^{-6} \quad T \odot$$

حساب شدة المجال Bعند نقطة P في الحالة التي بالرسم

$$B_{net} = \frac{\mu_0 I}{4\pi r}(\cos\theta_1 + \cos\theta_2)$$

at P



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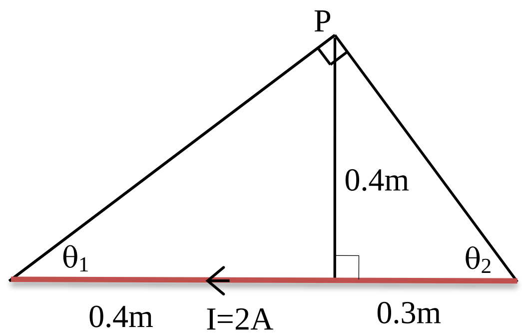
Ex13: the magnetic field at the point P is :-



(a) 6.54×10^{-7} T (b) 2.64×10^{-7} T

(c) 5.14×10^{-7} T (d) 3.74×10^{-7} T

Solution

$\theta_1 = \tan^{-1}\frac{0.4}{0.4} = 45^\circ$ $\theta_2 = \tan^{-1}\frac{0.4}{0.3} = 53.13^\circ$

$D = 0.4$ m $I = 2$ A

$$B_{net} = \frac{\mu \cdot I}{4\pi r}(\cos\theta_1 + \cos\theta_2)$$

$$= \frac{4\pi \times 10^{-7} \times 2}{4\pi \times 0.4}(\cos 45 + \cos 53.13)$$

$$= 6.54 \times 10^{-7} \text{ T } \otimes$$

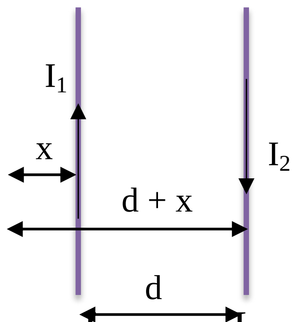
تحديد موضع النقطة التي عندها $B_{net} = 0$

في المجال المشترك لتيارين متوازيين I_1, I_2

بفرض $I_1 < I_2$

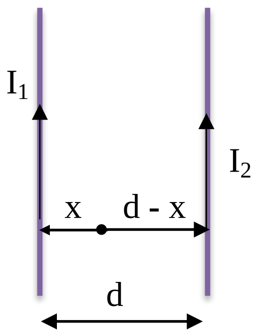
التيار ان في اتجاهين متضادين

النقطة خارجهما في ناحية التيار الأقل



$$\frac{I_1}{x} = \frac{I_2}{d + x}$$

التيار ان في اتجاه واحد النقطة بين السلكين وقريبة من التيار الأقل وفي المنتصف في حالة تساوي التيارين



$$\frac{I_1}{x} = \frac{I_2}{d - x}$$

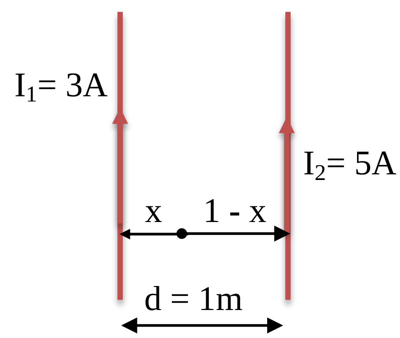
Ex11: Two long parallel wires the distance between them is 1 m, carrying a current in the same direction 3 A and 5 A. the point at which the magnetic field is zero (or the magnetic force at it is zero)

(a) 37.5 cm from I_1 (b) 37.5 cm from I_2

(c) 7.5 cm from I_1 (d) 7.5 cm from I_2

Solution

التياران في اتجاه واحد ⇐ النقطة بينهما



$$\frac{I_1}{x} = \frac{I_2}{1-x}$$

$$\frac{3}{x} = \frac{5}{1-x}$$

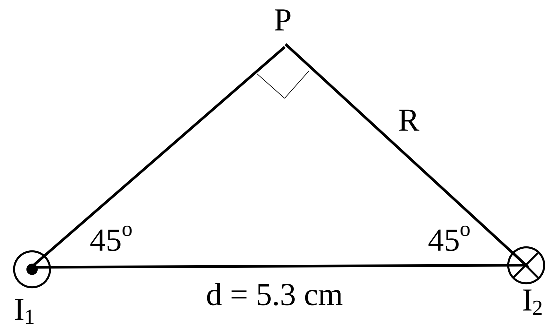
$$5x = 3 - 3x$$

$$8x = 3$$

$$\therefore \quad x = \frac{3}{8} = 0.375 \text{ m}$$

$$= 37.5 \text{ cm}$$ From I_1 الأضعف

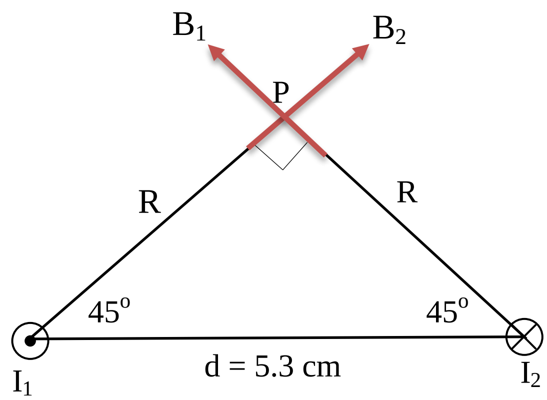
Ex12: The figure shows the cross section of the two long parallel wires carrying currents I_1=15A and I_2=32A in opposite direction. the magnitude of resultant magnetic field at P is



(a) 1.28×10^{-4} T (b) 1.88×10^{-4} T

(c) 1.05×10^{-4} T (d) 1.38×10^{-5} T

Solution



$$\sin 45 = \frac{R}{5.3}$$

$$R = 3.75 \text{ cm}$$

$$= 0.0375 \text{ m}$$

$$B_1 = 2\times10^{-7}\frac{I_1}{R}$$

$$= 2\times10^{-7}\frac{15}{0.0375} = 8 \times 10^{-5} \text{ T}$$

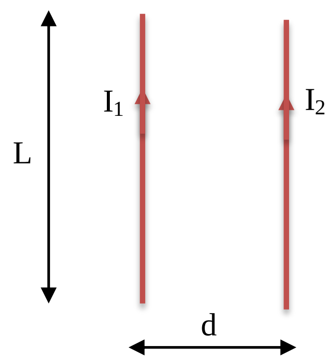
$$B_2 = 2\times10^{-7}\frac{I_2}{R}$$

$$= 2\times10^{-7}\frac{32}{0.0375} = 1.71 \times 10^{-4} \text{ T}$$

$$B_1 \perp B_2$$

$$B_{net} = \sqrt{B_1^2 + B_2^2} = 1.88 \times 10^{-4} \text{ T}$$

* القوة المتبادلة بين تيارين متوازيين

<table>
<tr><td>$$F = \frac{2 \times 10^{-7} \; I_1 I_2 L}{d} \quad (N)$$</td><td>
</td></tr>
<tr><td colspan="2">تيارا ن في نفس الاتجاه تكون القوة تجاذب
تيارا ن متعاكسي الاتجاه تكون القوة تنافر
اتجاه التيار لايؤثر على مقدار القوة بل على نوعها فقط</td></tr>
<tr><td colspan="2">Force per unit length is $$\frac{F}{L} = \frac{2 \times 10^{-7} \; I_1 I_2}{d} \quad (N / m)$$</td></tr>
</table>

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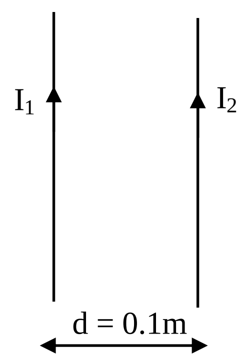
Ex14: The force of attraction per unit length between two parallel wires carrying the same current in the same direction is 4 × 10-7 N/m. If the separation between two wires is 10 cm, the magnitude of the current in each wire is:

(a) 0.2 A (b) 0.45 A (c) 0.67 A (d) 0.82 A (e) 0.91 A

Solution



$F = 4 \times 10^{-7}$ N/m

$I_1 = I_2 = I$

$$\frac{F}{L} = \frac{2 \times 10^{-7}\ I_1 I_2}{d}$$

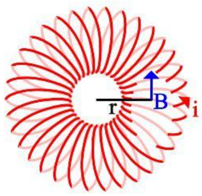
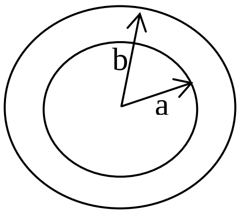
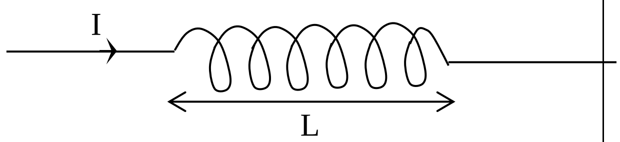
$$4 \times 10^{-7} = \frac{2 \times 10^{-7}\ I_1 I_2}{0.1}$$

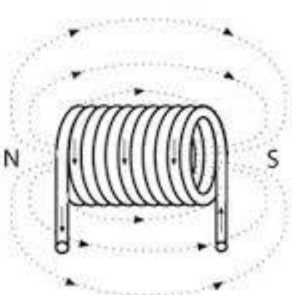
$$I^2 = 0.2$$

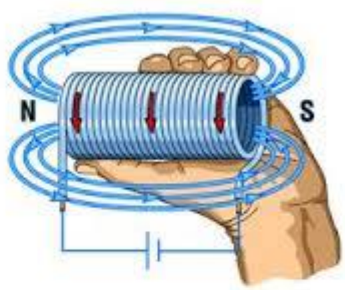
$$I_1 = I_2 = I = \sqrt{0.2} = 0.45\text{ A}$$

مصادر واشكال أخرى للمجال المغناطيس

$$\oint \vec{B}.d\vec{S} = \mu_0\, i_{inc} \qquad \text{Ampere's law}$$

Toroid الملف الاسطواني 	Solenoid الملف الحلزوني 
  حساب B يكون على بعد r من مركز الملف	 حساب B يكون على مركز الملف على المحور
r = بعد النقطة المطلوب حساب B عندها عن مركز الملف $B=\begin{cases} 0 & r < a \\ 2\times10^{-7}\dfrac{I\,N}{r} & a \le r \le b \\ 0 & r > b \end{cases}$ خارج الملف	$B = \dfrac{\mu_0\, I\, N}{L} \Rightarrow$ $B = \mu_0\, I\, n$ $\left(\dfrac{N}{L} = n\right)$





Ex16: A 500 turns solenoid is 30 cm long, has a radius of 0.5 cm and carries a current of 2 A. The magnitude of the magnetic field at the center of the solenoid is:

(a) 8.2×10^{-3} T (b) 9.9×10^{-8} T (c) 1.3×10^{-3} T (d) 4.2×10^{-3} T

Solution

N = 500 L = 0.3 m I = 2 A

$$B = \frac{\mu_0 \; I \; N}{L} = \frac{4\pi \times 10^{-7} \times 2 \times 500}{0.3} = 4.2 \times 10^{-3} \quad T$$

Ex17: A 1000 turns toroid has an inner radius of 20 cm and its outer radius is 25 cm carry a current of 1 A. the magnetic field at a point r = 23 cm is

(a) 8.2×10^{-3} T (b) 9.9×10^{-7} T (c) 1.3×10^{-3} T (d) 8.7×10^{-4} T

Solution

a = 0.2 m b = 0.25 m I = 1 A N = 1000

r = 0.23 m $a < r < b$

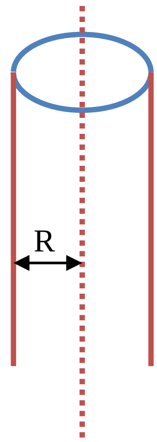
$$\Rightarrow \quad B = 2 \times 10^{-7} \frac{I\,N}{r}$$

$$\frac{2 \times 10^{-7} \times 1 \times 1000}{0.23}$$

$$= 8.7 \times 10^{-4} T$$

المجال المغناطيسي لسلك اسطواني مستقيم لانهائي الطول

Long wire

$$B=\begin{cases} 2\times10^{-7}\left(\dfrac{I}{R^2}\right)r & r<R \quad \text{داخل السلك} \\ 2\times10^{-7}\dfrac{I}{r} & r\geq R \quad \text{على سطح السلك أو خارجه} \end{cases}$$ نصف قطر السلك	
r هي بعد النقطة المطلوب تحديد B عندها عن محور السلك.	

Ex8: A long cylinder wire of diameter 4 mm carries a steady current 30 A uniformly distributed over the cross section. The magnetic field at a distance of 1 mm from the axis of the wire is:

(a) 6 mT (b) 3 mT (c) 1.5 mT (d) 0.38 mT (e) 1.5 mT

Solution

$D = 4\times10^{-3}$ m $\xrightarrow{\div 2}$ $R = 4\times10^{-3}$ m

$I = 30$ A $\qquad r = 10^{-3}$ m & R داخل السلك

$$B = 2\times10^{-7}\left(\frac{I}{R^2}\right)r = 2\times10^{-7}\left(\frac{30}{(2\times10^{-3})^2}\right)10^{-3}$$

$$= 1.5\times10^{-3}\ \text{T} = 1.5\ \text{mT}$$

Ex9: What must be the radius R of a long current carrying wire if the magnetic field at r_1 = 2 cm (inside the wire) is equal to three times the magnetic field at r_2 = 8 cm (outside the wire)

(a) 5.2 cm (b) 3.8 cm (c) 2.3 cm (d) 4.4 cm (e) 7.3 cm

Solution

$r_1 = 2\text{ cm} = 0.02\text{ m}$

$r_2 = 0.08\text{ m}$

$$B_{1\,in} = 3\,B_{2\,out}$$

$$2\times10^{-7}\,\frac{I}{R^2}\,r_1 = 3\times 2\times10^{-7}\,\frac{I}{r_2}$$

$$R^2 = \frac{r_1\,r_2}{3}$$

$$\therefore\quad R = \sqrt{\frac{0.02\times0.08}{3}}$$

$$= 0.023\text{ m}$$

$$= 2.3\text{ cm}$$