

MANYETİK ALANIN KAYNAKLARI

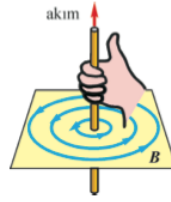
- Biot-Savart Yasası
- İki Paralel İletken Arasındaki Manyetik Alan
- Ampere Yasası
- Bir Solenoidin Manyetik Alanı
- Manyetik Akı
- Manyetizmada Gauss Yasası
- Yerdeğiştirme Akımı ve Ampere Yasasının Genel Biçimi



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BIOT-SAVART YASASI

I akımı geçen doğrusal bir telin manyetik alanı.

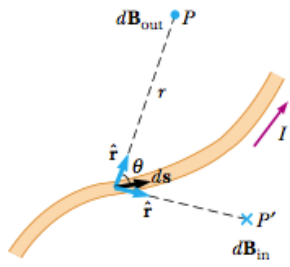


Gözlenen özellikler:

- Manyetik alan çizgileri tele dik düzlemde, merkezi tel olan çemberler.
- Yönü, sağ-el kuralına göre, başparmak akım yönündeyken, dört parmağın kıvrıldığı yönde.
- Manyetik alan şiddeti r uzaklığıyla ters orantılı.

Bu özellikleri ilk kez gözleyen Jean-Baptiste Biot ve Felix Savart, her türlü akım için manyetik alan ifadesini keşfettiler.

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

$$\mu_0 = 4\pi \times 10^{-7} \text{ T} \cdot \text{m/A}$$

$\mu_0 \rightarrow$ serbest uzayın geçirgenliği

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

Biot-Savart Yasası

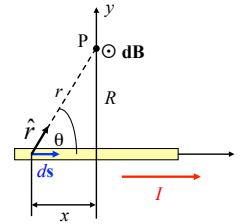
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Örnek: İnce Doğrusal Bir İletkeni Çevreleyen Manyetik Alan

➤ L uzunluklu düz bir tel

- L uzunluklu ince bir telin I sabit akımı taşır .
- P deki toplam B alanını bulalım.

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



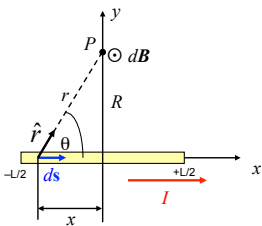
$d\mathbf{s} \times \hat{\mathbf{r}}$ Her zaman sayfadan dışa doğrudur.
 $ds \sin \theta$ büyüklüğe sahiptir.

Böylece $d\mathbf{B}$ nin büyüklüğü aşağıdaki gibi verilir:

$$dB = \frac{\mu_0 I ds \sin \theta}{4\pi r^2} = \frac{\mu_0 I dx \sin \theta}{4\pi r^2}$$

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➤ L uzunluklu düz bir tel



$$dB_z = \frac{\mu_0 I ds \sin \theta}{4\pi r^2} = \frac{\mu_0 I |dx| \sin \theta}{4\pi r^2}$$

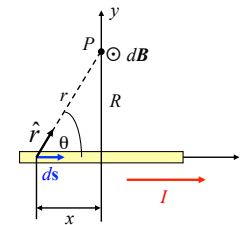
$$\frac{R}{r} = \sin \theta \quad ; \quad r = \sqrt{x^2 + R^2}$$

$$dB_z = \frac{\mu_0 I}{4\pi} \frac{R |dx|}{(x^2 + R^2)^{3/2}}$$

$$B_z = \frac{\mu_0 I R}{4\pi} \int_{-L/2}^{L/2} \frac{dx}{(x^2 + R^2)^{3/2}} = \frac{\mu_0 I R}{4\pi} \frac{x}{R^2 (x^2 + R^2)^{1/2}} \Big|_{-L/2}^{L/2} = \frac{\mu_0 I}{4\pi R} \left(\frac{L}{\sqrt{L^2/4 + R^2}} \right)$$

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➤ L uzunluklu düz bir tel



$$B_z = \frac{\mu_0 I}{4\pi R} \left(\frac{L}{\sqrt{L^2/4 + R^2}} \right)$$

$(L/R) \rightarrow \infty$ limitinde

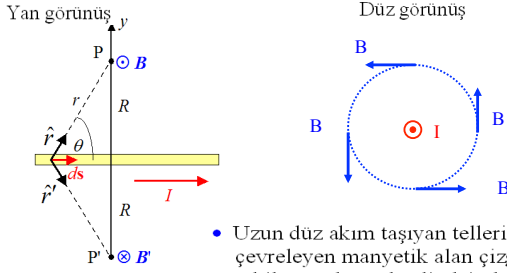
$$\left(\frac{L}{\sqrt{L^2/4 + R^2}} \right) = \frac{L/R}{\sqrt{(L/R)^2/4 + 1}} \approx 2$$

Uzun düz bir telin manyetik alanı:

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

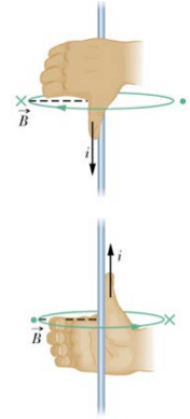
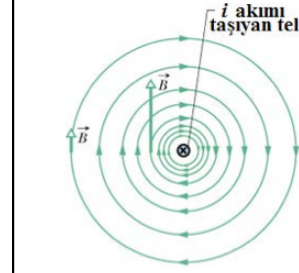
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➤ L uzunluklu düz bir tel



- Uzun düz akım taşıyan telleri çevreleyen manyetik alan çizgileri tel ile ortak merkezli dairelerdir ve düzlemlerde tele diktir.
- **B** nin büyüklüğü tel üzerinde merkezlenmiş her bir daire üzerine sabittir.

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Example 30.1 Magnetic Field Surrounding a Thin, Straight Conductor

Interactive

Consider a thin, straight wire carrying a constant current I and placed along the x axis as shown in Figure 30.3. Determine the magnitude and direction of the magnetic field at point P due to this current.

Solution From the Biot-Savart law, we expect that the magnitude of the field is proportional to the current in the wire and decreases as the distance a from the wire to point P increases. We start by considering a length element ds located a distance x from P . The direction of the magnetic field at point P due to the current in this element is out of the page because $ds \times \hat{r}$ is out of the page. In fact, because *all* of the current elements $I ds$ lie in the plane of the page at point P , they all produce a magnetic field directed out of the page at point P . Thus, we have the direction of the magnetic field at point P , and we need only find the magnitude. Taking the origin at O and letting point P be along the positive y axis, with \hat{k} being a unit vector pointing out of the page, we see that

$$ds \times \hat{r} = |ds \times \hat{r}| \hat{k} = (dx \sin \theta) \hat{k}$$

where $|ds \times \hat{r}|$ represents the magnitude of $ds \times \hat{r}$. Because \hat{r} is a unit vector, the magnitude of the cross

product is simply the magnitude of ds , which is the length dx . Substitution into Equation 30.1 gives

$$d\mathbf{B} = (dB) \hat{k} = \frac{\mu_0 I}{4\pi} \frac{dx \sin \theta}{r^2} \hat{k}$$

Because all current elements produce a magnetic field in the \hat{k} direction, let us restrict our attention to the magnitude of the field due to one current element, which is

$$(1) \quad dB = \frac{\mu_0 I}{4\pi} \frac{dx \sin \theta}{r^2}$$

To integrate this expression, we must relate the variables θ , x , and r . One approach is to express x and r in terms of θ . From the geometry in Figure 30.3a, we have

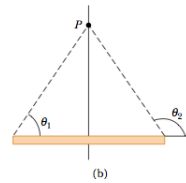
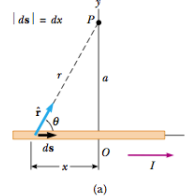
$$(2) \quad r = \frac{a}{\sin \theta} = a \csc \theta$$

Because $\tan \theta = a/(-x)$ from the right triangle in Figure 30.3a (the negative sign is necessary because ds is located at a negative value of x), we have

$$x = -a \cot \theta$$

Taking the derivative of this expression gives

$$(3) \quad dx = a \csc^2 \theta d\theta$$



Substitution of Equations (2) and (3) into Equation (1) gives

$$(4) \quad dB = \frac{\mu_0 I}{4\pi} \frac{a \csc^2 \theta \sin \theta d\theta}{a^2 \csc^2 \theta} = \frac{\mu_0 I}{4\pi a} \sin \theta d\theta$$

an expression in which the only variable is θ . We now obtain the magnitude of the magnetic field at point P by integrating Equation (4) over all elements, where the subtending angles range from θ_1 to θ_2 as defined in Figure 30.3b:

$$B = \frac{\mu_0 I}{4\pi a} \int_{\theta_1}^{\theta_2} \sin \theta d\theta = \frac{\mu_0 I}{4\pi a} (\cos \theta_1 - \cos \theta_2) \quad (30.4)$$

We can use this result to find the magnetic field of *any* straight current-carrying wire if we know the geometry and hence the angles θ_1 and θ_2 . Consider the special case of an infinitely long, straight wire. If we let the wire in Figure 30.3b become infinitely long, we see that $\theta_1 = 0$ and $\theta_2 = \pi$ for length elements ranging between positions $x = -\infty$ and $x = +\infty$. Because $(\cos \theta_1 - \cos \theta_2) = (\cos 0 - \cos \pi) = 2$, Equation 30.4 becomes

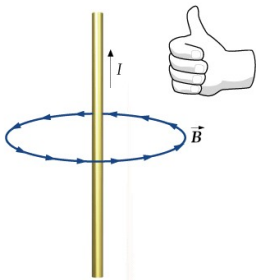
$$B = \frac{\mu_0 I}{2\pi a} \quad (30.5)$$

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Düz bir akım taşıyan iletkenin manyetik alanı

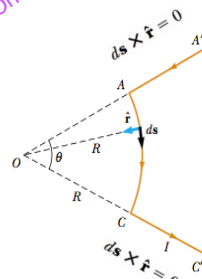
□ Örnek: Uzun düz bir tel



Iron filings

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Örnek Kavisli Bir Tel Parçasından Kaynaklanan manyetik alanı



Gösterilen tel parçasından dolayı O noktasındaki manyetik alanı hesaplayalım. Tel düzgün I akımı taşır ve iki düz parçadan ve θ açısı ile yayılan R yarıçaplı dairesel bir artkan oluşur.

$A'A$ ve CC' parçalarından dolayı manyetik alan sıfırdır çünkü ds bu yollar boyunca \hat{r} 'ye paraleldir.

AC yolu boyunca, ds ve \hat{r} diktir. $|ds \times \hat{r}| = ds$

$$d\mathbf{B} = \frac{\mu_0}{4\pi} \frac{I ds \times \hat{r}}{r^2}$$

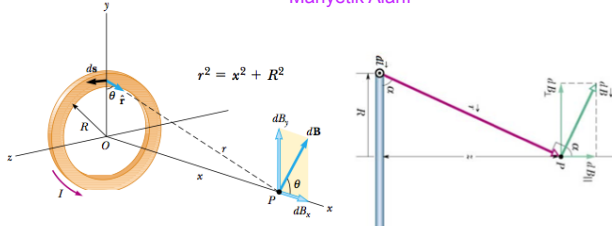
$$B = \frac{\mu_0 I}{4\pi R^2} \int ds = \frac{\mu_0 I}{4\pi R^2} \int R d\theta = \frac{\mu_0 I}{4\pi R} \int d\theta = \frac{\mu_0 I}{4\pi R} \theta$$

Not: B alanı ilmek merkezindeyken, $\theta=2\pi$ dir.

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

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Örnek : Çembersel Bir Akım İlmeğinin Eksenini Üzerindeki Kaynaklanan Manyetik Alanı



$$dB = \frac{\mu_0 I}{4\pi} \frac{|ds \times \hat{r}|}{r^2} = \frac{\mu_0 I}{4\pi} \frac{ds}{(x^2 + R^2)}$$

$$dB_x = dB \cos \theta \quad \mathbf{B} = B_x \hat{i}$$

$$B_x = \oint dB \cos \theta = \frac{\mu_0 I}{4\pi} \oint \frac{ds \cos \theta}{x^2 + R^2}$$

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$$\cos \theta = R / (x^2 + R^2)^{1/2} \quad \oint ds = 2\pi R$$

$$B_x = \frac{\mu_0 I R}{4\pi (x^2 + R^2)^{3/2}} \oint ds = \frac{\mu_0 I R^2}{2(x^2 + R^2)^{3/2}}$$

$$B = \frac{\mu_0 I}{2R} \quad (x = 0)$$

ilmeğin merkezindeki manyetik alan

$$B \approx \frac{\mu_0 I R^2}{2x^3} \quad (x \gg R)$$

$$\mu = I(\pi R^2) \quad B \approx \frac{\mu_0 \mu}{2\pi x^3}$$

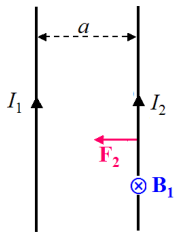
$$E = k_e(2qa/y^3)$$

$$2qa = p$$

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Örnek : İki Paralel İletken Arasındaki Manyetik Kuvvet

İki paralel tel



I_1 Akımlı telden a uzaklıkta telden dolayı oluşan manyetik alan aşağıdaki gibi verilir:

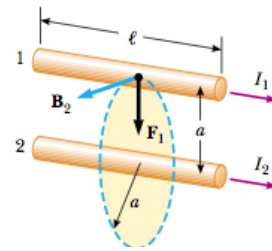
$$B_1 = \frac{\mu_0 I_1}{2\pi a}$$

$$\mathbf{F}_2 = I_2 L \times \mathbf{B}_1$$

$$F_2 = I_2 L B_1 = I_2 L \frac{\mu_0 I_1}{2\pi a} = \frac{\mu_0 I_1 I_2}{2\pi} \frac{L}{a}$$

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İki Paralel İletken Arasındaki Manyetik Kuvvet



$$\mathbf{F}_1 = I_1 \ell \times \mathbf{B}_2$$

$$F_1 = I_1 \ell B_2$$

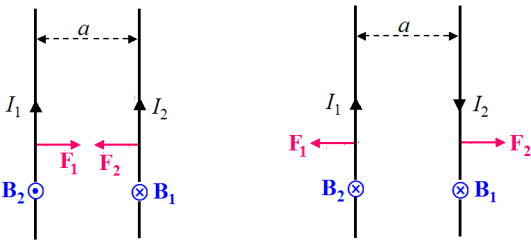
$$F_1 = I_1 \ell B_2 = I_1 \ell \left(\frac{\mu_0 I_2}{2\pi a} \right) = \frac{\mu_0 I_1 I_2}{2\pi a} \ell$$

$$\frac{F_B}{\ell} = \frac{\mu_0 I_1 I_2}{2\pi a}$$

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Paralel İletkenler Arasındaki Kuvvet

İki paralel tel

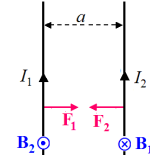


Aynı yönde akım taşıyan paralel iletkenler birbirini çeker. Zıt yönde akım taşıyan paralel iletkenler birbirini iter.

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İki Paralel İletken Arasındaki Manyetik Kuvvet

Amperere'nin tanımı



$$B_1 = \frac{\mu_0 I_1}{2\pi a}$$

$$\mathbf{F}_2 = I_2 L \times \mathbf{B}_1$$

$$F_2 = \frac{\mu_0 I_1 I_2}{2\pi} \frac{L}{a}$$

$$\frac{F_B}{\ell} = \frac{\mu_0 I_1 I_2}{2\pi a}$$

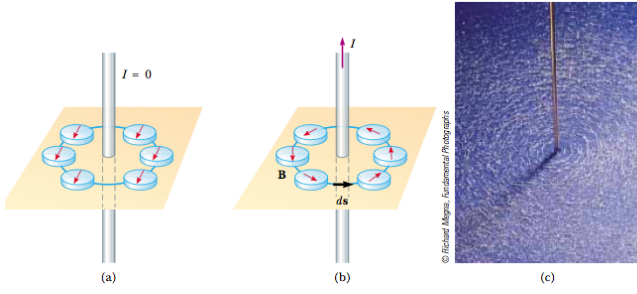
Seçilen tanım $a = L = 1\text{m}$ içindir $I_1 = I_2 = 1$ amper iken, amper $F_2 = 2 \times 10^{-7} \text{N}$ şeklinde elde edilen değer için ifade edilir.

Bu seçim iki şey yapar (1) Bu, amperin (ve aynı zamanda voltun) gündelik yaşam için çok uygun bir büyüklüğe sahip olmasını sağlar ve (2) $\mu_0 = 4\pi \times 10^{-7}$ büyüklüğünü belirler. Not : $\epsilon_0 = 1/(\mu_0 c^2)$ dir. Diğer birimlerin tümü hemen otomatik olarak uyum sağlar.

Aralarında 1 m mesafe bulunan ve özdeş akımlar taşıyan paralel iki uzun tel arasında, birim uzunluğa etkiyen kuvvet $2 \times 10^{-7} \text{N/m}$ olduğunda, tellerden geçen akım 1 amper (A) olur.

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AMPERE YASASI



(a)

(b)

(c)

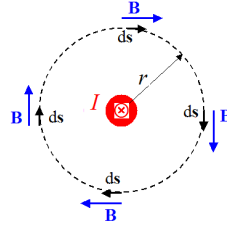
$$\oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 I$$

Ampere yasası

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AMPERE YASASI

□ Ampere Yasası : Dairesel bir yol



- I akımı taşıyan telin üzerinde merkezlenmiş her hangi bir R yarıçaplı dairesel yol düşünelim.
- Bu yol çevresindeki $\mathbf{B} \cdot d\mathbf{s}$ skaler çarpımını bulalım
- Yol boyunca her noktada \mathbf{B} ve $d\mathbf{s}$ nin paralel olduğuna dikkat edelim
- Ayrıca \mathbf{B} nin büyüklüğü bu yol üzerinde sabittir. Böylece daire çevresinde bütün $\mathbf{B} \cdot d\mathbf{s}$ terimlerin toplamı aşağıdaki gibidir:

Önceki Biot-Savart kanunundan $B = \frac{\mu_0 I}{2\pi r}$ elde etmiştik.

$$\oint \mathbf{B} \cdot d\mathbf{s} = B \oint ds = \frac{\mu_0 I}{2\pi r} (2\pi r) = \mu_0 I$$

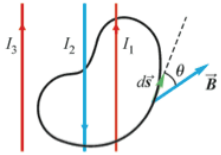
olur. Bu Ampere yasasıdır.

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Ampere Yasası

Kapalı bir eğri boyunca manyetik alanın izdüşümünün integrali, bu eğrinin çevrelediği herhangi bir yüzeyi kesen net akım ile orantılıdır:

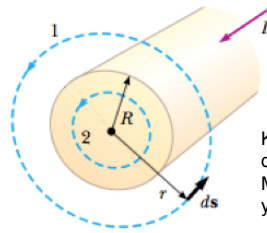
$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_c \quad (\text{Ampere Yasası})$$



- I_c kapalı eğri içinde kalan net akımdır. Bir yöndeki akım pozitif ise zıt yöndeki akım negatif alınır.
- Eğri dışında kalan akımlar hesaba katılmaz.
- Problemin simetrisine uygun bir eğri seçilirse, integral almaya gerek kalmaz.

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Örnek:

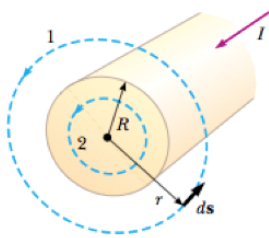


Kararlı bir I akımı taşıyan R yarıçaplı uzun düz bir telin dışında $r \geq R$ için oluşturduğu Manyetik alanını (B), Ampere Yasasından yararlanarak bulabiliriz;

$$\oint \mathbf{B} \cdot d\mathbf{s} = B \oint ds = B(2\pi r) = \mu_0 I$$

$$\star B = \frac{\mu_0 I}{2\pi r} \quad (\text{for } r \geq R)$$

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$$\oint \mathbf{B} \cdot d\mathbf{s} = B \oint ds = B(2\pi r) = \mu_0 I$$

$$B = \frac{\mu_0 I}{2\pi r} \quad (\text{for } r \geq R)$$

$$\frac{I'}{I} = \frac{\pi r^2}{\pi R^2}$$

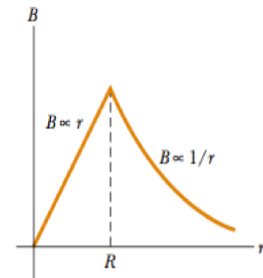
$$I' = \frac{r^2}{R^2} I$$

$$\oint \mathbf{B} \cdot d\mathbf{s} = B(2\pi r) = \mu_0 I' = \mu_0 \left(\frac{r^2}{R^2} I \right)$$

$$B = \left(\frac{\mu_0 I}{2\pi R^2} \right) r \quad (\text{for } r < R)$$

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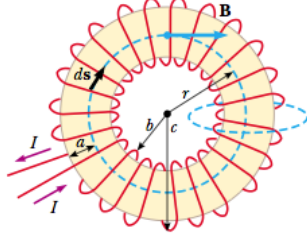
$$B = \left(\frac{\mu_0 I}{2\pi R^2} \right) r \quad (\text{for } r < R)$$



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Örnek: Bir Toroidin oluşturduğu Manyetik Alan

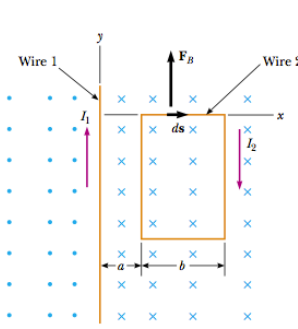
Bir toroid gösterildiği gibi bir daire içerisine bükülmüş bir solenoid olarak düşünülebilir. Toroiddeki dairesel yol boyunca Ampere kanununu uygulayabiliriz.



$$\oint \mathbf{B} \cdot d\mathbf{s} = B \oint ds = B(2\pi r) = \mu_0 NI$$

$$B = \frac{\mu_0 NI}{2\pi r}$$

Örnek: Bir Akım Elemanına Etkiyen Manyetik Kuvvet



$$\mathbf{B} = \frac{\mu_0 I_1}{2\pi x} (-\hat{\mathbf{k}})$$

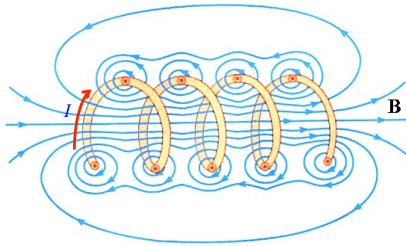
$$d\mathbf{F}_B = \frac{\mu_0 I_1 I_2}{2\pi x} [\hat{\mathbf{i}} \times (-\hat{\mathbf{k}})] dx = \frac{\mu_0 I_1 I_2}{2\pi} \frac{dx}{x} \hat{\mathbf{j}}$$

$$\mathbf{F}_B = \frac{\mu_0 I_1 I_2}{2\pi} \ln x \Big|_a^{a+b} \hat{\mathbf{j}}$$

$$\mathbf{F}_B = \frac{\mu_0 I_1 I_2}{2\pi} \ln \left(1 + \frac{b}{a} \right) \hat{\mathbf{j}}$$

Bir Solenoidin Manyetik Alanı

Solenoidin bobinleri yakın aralıklarla yerleştirildiğinde, her bir dönüşe dairesel ilmek olarak bakılabilir ve net manyetik alan her bir ilmek için manyetik alanların vektör toplamıdır. Bu, solenoid içinde yaklaşık olarak sabit olan bir manyetik alan üretir, ve solenoidin dışında sifira yakındır.

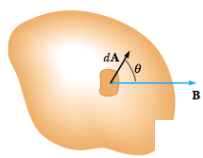


$$\oint \mathbf{B} \cdot d\mathbf{s} = \int_{\text{path 1}} \mathbf{B} \cdot d\mathbf{s} = B \int ds = B\ell$$

$$\oint \mathbf{B} \cdot d\mathbf{s} = B\ell = \mu_0 NI$$

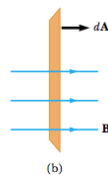
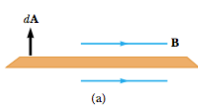
$$B = \mu_0 \frac{N}{\ell} I = \mu_0 nI$$

MANYETİK AKI



$$\Phi_B = \int \mathbf{B} \cdot d\mathbf{A}$$

$$\Phi_B = BA \cos \theta$$



Akının birimi 1 Weber (Wb) = 1 T.m²

Example 30.8 Magnetic Flux Through a Rectangular Loop

Interactive

A rectangular loop of width a and length b is located near a long wire carrying a current I (Fig. 30.22). The distance between the wire and the closest side of the loop is c . The wire is parallel to the long side of the loop. Find the total magnetic flux through the loop due to the current in the wire.

The factor $1/r$ indicates that the field varies over the loop, and Figure 30.22 shows that the field is directed into the page at the location of the loop. Because \mathbf{B} is parallel to $d\mathbf{A}$ at any point within the loop, the magnetic flux through an area element dA is

$$\Phi_B = \int B dA = \int \frac{\mu_0 I}{2\pi r} dA$$

To integrate, we first express the area element (the tan region in Fig. 30.22) as $dA = b dr$. Because r is now the only variable in the integral, we have

$$\Phi_B = \frac{\mu_0 I b}{2\pi} \int_c^{c+a} \frac{dr}{r} = \frac{\mu_0 I b}{2\pi} \ln r \Big|_c^{c+a}$$

$$(1) \quad \Phi_B = \frac{\mu_0 I b}{2\pi} \ln \left(\frac{c+a}{c} \right) = \frac{\mu_0 I b}{2\pi} \ln \left(1 + \frac{a}{c} \right)$$

What if? Suppose we move the loop in Figure 30.22 very far away from the wire. What happens to the magnetic flux?

Answer The flux should become smaller as the loop moves into weaker and weaker fields.

As the loop moves far away, the value of c is much larger than that of a , so that $a/c \rightarrow 0$. Thus, the natural logarithm in Equation (1) approaches the limit

$$\ln \left(1 + \frac{a}{c} \right) \rightarrow \ln(1 + 0) = \ln(1) = 0$$

and we find that $\Phi_B \rightarrow 0$ as we expected.

Figure 30.22 (Example 30.8) The magnetic field due to the wire carrying a current I is not uniform over the rectangular loop.

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$$\oint \mathbf{B} \cdot d\mathbf{A} = 0$$

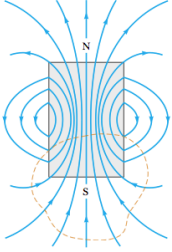


Figure 30.23 The magnetic field lines of a bar magnet form closed loops. Note that the net magnetic flux through a closed surface surrounding one of the poles (or any other closed surface) is zero. (The dashed line represents the intersection of the surface)

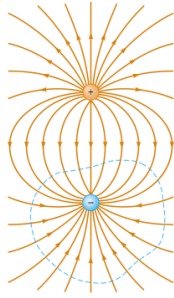
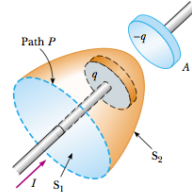


Figure 30.24 The electric field lines surrounding an electric dipole begin on the positive charge and terminate on the negative charge. The electric flux through a closed surface surrounding one of the charges is not zero.

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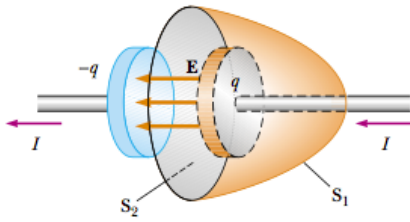
$$I_d = \epsilon_0 \frac{d\Phi_E}{dt}$$

$$\oint \mathbf{B} \cdot d\mathbf{s} = \mu_0(I + I_d) = \mu_0 I + \mu_0 \epsilon_0 \frac{d\Phi_E}{dt}$$

$$\Phi_E = EA = \frac{q}{\epsilon_0}$$

$$I_d = \epsilon_0 \frac{d\Phi_E}{dt} = \frac{dq}{dt}$$

Figure 30.25 Two surfaces S_1 and S_2 near the plate of a capacitor are bounded by the same path P . The conduction current in the wire passes only through S_1 . This leads to a contradiction in Ampère's law that is resolved only if one postulates a displacement current through S_2 .



$$I_d = \epsilon_0 \frac{d\Phi_E}{dt} = \frac{dq}{dt}$$

$$\oint \mathbf{B} \cdot d\mathbf{s} = \mu_0(I + I_d) = \mu_0 I + \mu_0 \epsilon_0 \frac{d\Phi_E}{dt}$$

MAXWELL DENKLEMLERİ

$$\oint_S \mathbf{E} \cdot d\mathbf{A} = \frac{q}{\epsilon_0}$$

Gauss's law

$$\oint_S \mathbf{B} \cdot d\mathbf{A} = 0$$

Gauss's law in magnetism

$$\oint \mathbf{E} \cdot d\mathbf{s} = -\frac{d\Phi_B}{dt}$$

Faraday's law

$$\oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 I + \epsilon_0 \mu_0 \frac{d\Phi_E}{dt}$$

Ampère-Maxwell law