KK 2916626, Induksi Magnetik

Program Studi : S1 Pendidikan IPA
FAKULTAS KEGURUAN DAN ILMU PENDIDIKAN
UNIVERSITAS SEBELAS MARET (UNS) SURAKARTA

Pertemuan ke-4 (Kelas A) : Selasa, 17 Maret 2020 Pk. 12.40 – 15.00 wib

E learning :

INDUKSI MAGNETIK (Review materi)

1. Gaya Magnet

Gaya Lorentz pada Kawat Sejajar

Medan magnet di kawat 1 akibat kawat ke-2

$$B_2 = \frac{\mu_0 I_2}{2\pi a}$$

Gaya magnet padakawat 2 disebabkanoleh medan $\mathbf{B}_2$(semua yang)

$$|F_B| = I_1 l_1 |B_2|$$

$$|F_B| = \frac{I_1 l_1 \mu_0 I_2}{2\pi a} = \frac{\mu_0 I_1 I_2}{2\pi a} l_1$$

Gaya pada kawat 1 yang disebabkan oleh kawat 2

$$F_1 = \frac{\mu_0 I_1 I_2}{2\pi a} l_1$$

Gaya pada kawat 2 yang disebabkan oleh kawat 1

$$F_2 = \frac{\mu_0 I_1 I_2}{2\pi a} l_2$$

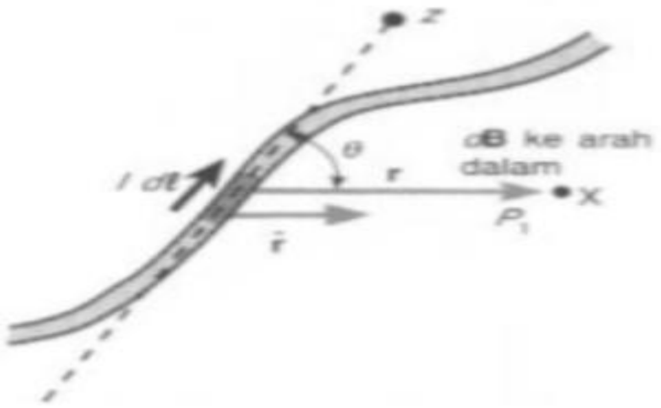
Gaya / satuan panjang

$$F = \frac{\mu_0}{2\pi} \frac{i_1 i_2}{a} l$$

Kawat yg arah arusnya searah akan tarik-menarik.
Kawat yang arusnya berlawanan arah akan tolak-menolak

2. Hukum Biot-Savart

Medan magnet di sekitar elemen panjang kawat berarus adalah:



$$d\vec{B} = k_m \frac{i d\vec{l} \times \hat{r}}{r^3}$$

$$k_m = \frac{\mu_0}{4\pi} = 10^{-7}\, Wb / A \cdot m$$

μ_0 = permeabilitas ruang hampa

$$d\vec{B} = \frac{\mu_o i}{4\pi} \frac{d\vec{l} \times \hat{r}}{r^3} \qquad dB = \frac{\mu_o i}{4\pi} \frac{dl \sin\theta}{r^2}$$

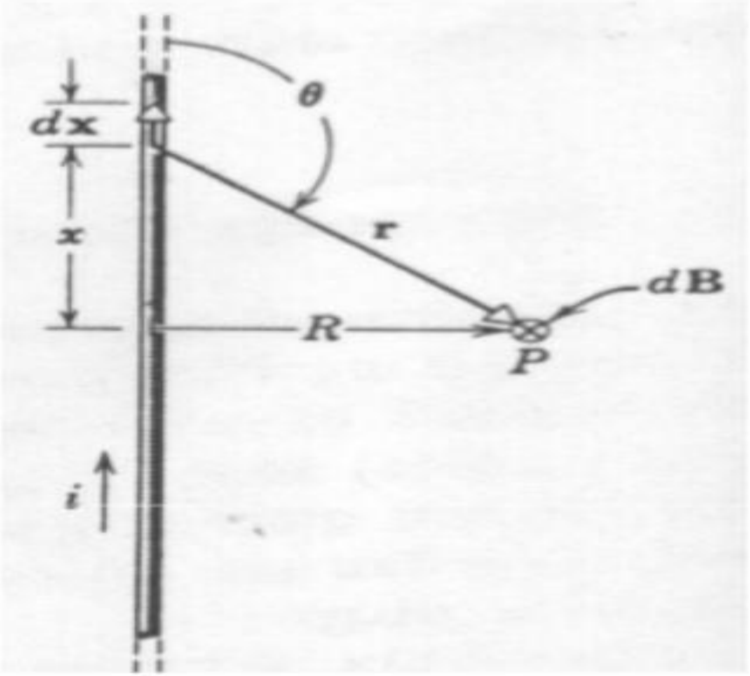
Medan magnet resultan di p: $B = \int dB$

Hukum Biot Savart : Kawat Lurus panjang

$$B = \int dB = \frac{\mu_o i}{4\pi} \int_{x=-\infty}^{x=\infty} \frac{dx \sin\theta}{r^2}$$

dx, sin θ, dan r adalah variabel

Ingat: agar integral dapat diselesaikan, maka ruas kanan harus memiliki 1 variabel



$$r = \sqrt{x^2 + R^2}$$

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

$$B = \frac{\mu_o i}{4\pi} \int_{x=-\infty}^{x=\infty} \frac{R\,dx}{(x^2 + R^2)^{\frac{3}{2}}}$$

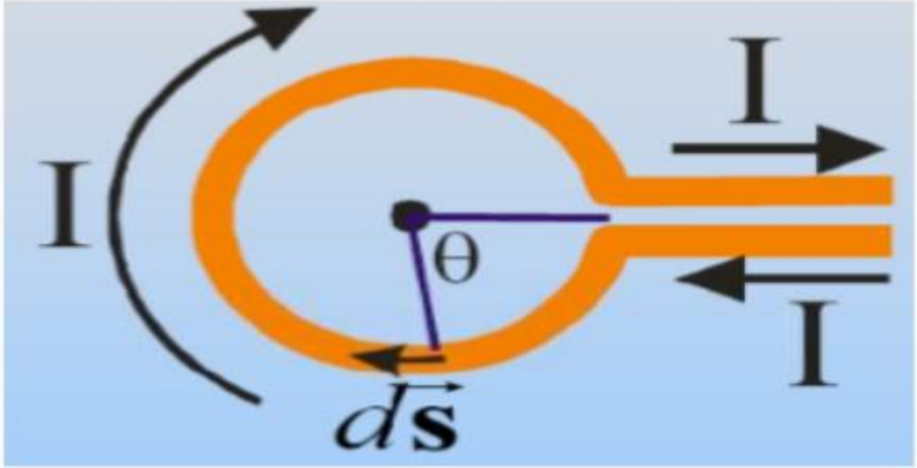
$$B = \frac{\mu_o i}{4\pi} \left. \frac{x}{(x^2 + R^2)^{\frac{1}{2}}} \right|_{x=-\infty}^{x=\infty}$$

$$B = \frac{\mu_o i}{2\pi R}$$

Kemanakah arah medan magnet???

Hukum Biot Savart : Kawat melingkar

Tinjau sebuah koil dengan radius *R* dan arus *I*



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

$$B = \int dB = \int_0^{2\pi} \frac{\mu_0 I}{4\pi}\frac{d\theta}{R}$$

$$= \frac{\mu_0 I}{4\pi R}\int_0^{2\pi} d\theta = \frac{\mu_0 I}{4\pi R}(2\pi)$$

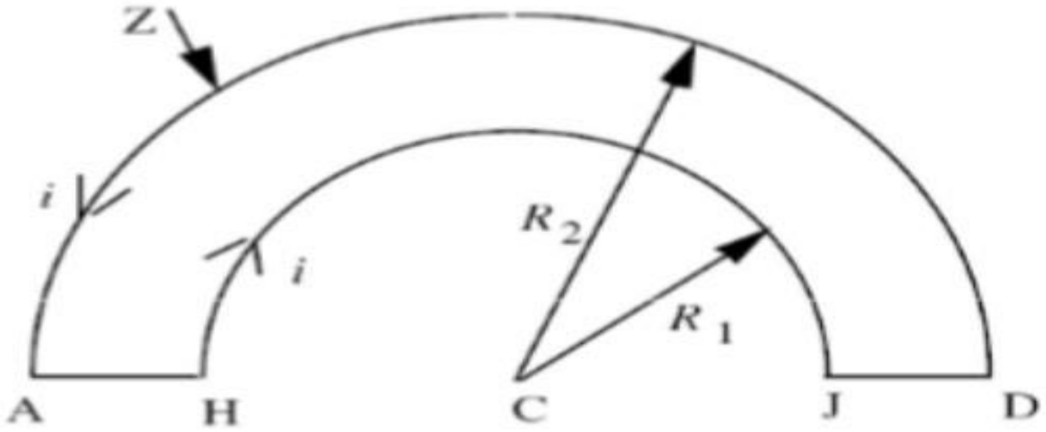
$$\vec{\mathbf{B}} = \frac{\mu_0 I}{2R}$$

Masuk bidang

Bagaimana dengan lilitan kawat dengan radius *R* dengan N lilitan???

$$B = \frac{\mu_o iN}{2R}$$

Contoh Soal :



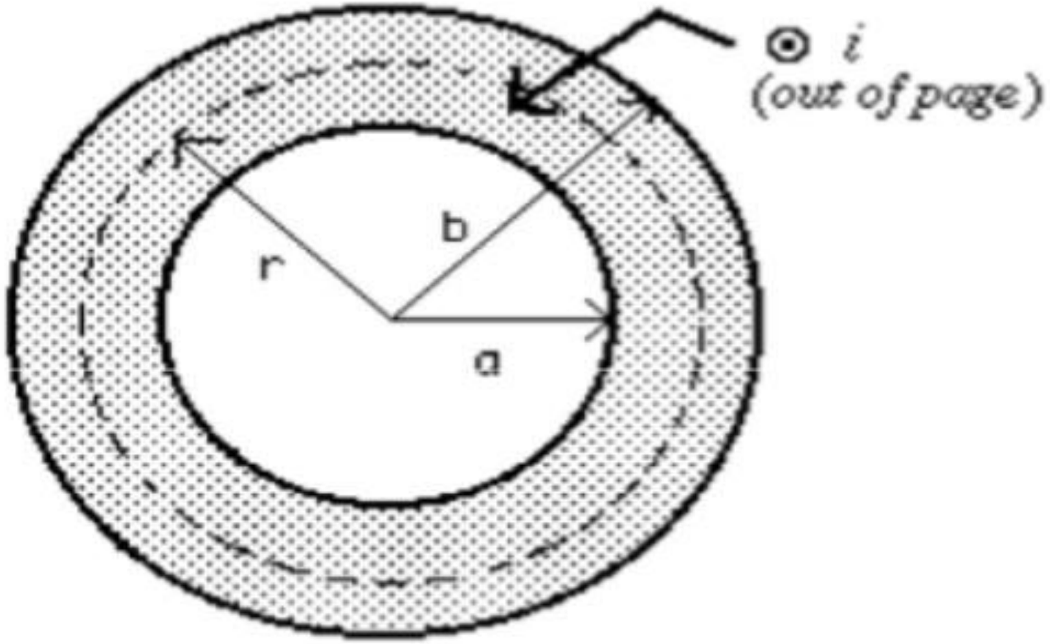
Gunakan Hukum Biot-Savart untuk Menghitung medan magnet B di C, Yakni pusat bersama dari busur-busur Setengah lingkaran AH dan HJ, yang Jari-jarinya R_2 dan R_1, yang membentuk Bagian dari rangkaian AD/HA yang Mengangkut arus *i*

$$B = \frac{\mu_o i}{4\pi} \frac{dl \sin\theta}{r^2}$$

$$B = \frac{\mu_o i}{4\pi} \int_D^A \frac{dl}{R_2^{\,2}} - \frac{\mu_o i}{4\pi} \int_J^H \frac{dl}{R_1^{\,2}}$$

$$B = \frac{\mu_o i}{4} \left(\frac{1}{R_2} - \frac{1}{R_1} \right)$$

Contoh soal :



Gambar di samping memperlihatkan Sebuah penghantar silinder yang kosong dengan jari-jari a dan b yang Mengangkut arus i yang tersebar Secara uniform pada penampangnya.

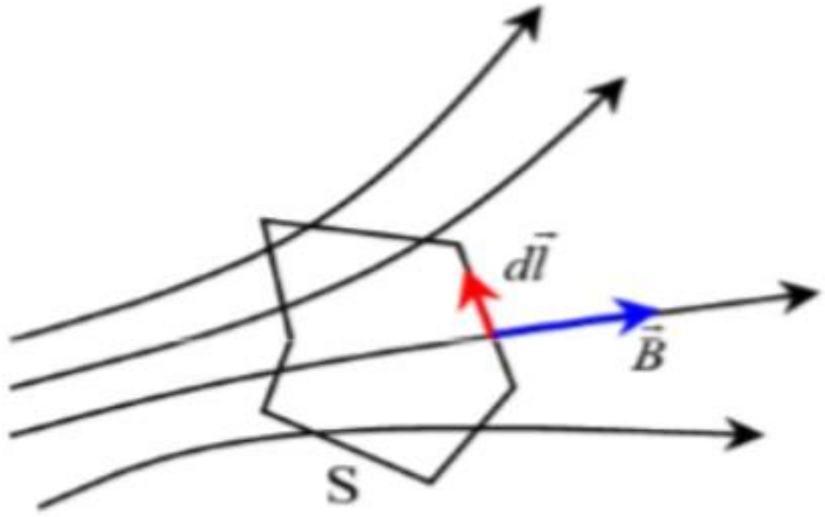
a) Perlihatkan bahwa medan magnet B untuk titik-titik di dalam badan penghantar ($a<r<b$)

$$B = \frac{\mu_o i}{2\pi(b^2 - a^2)} \frac{r^2 - a^2}{r}$$

b) Buatlah gambar kasar sifat umum B(r) dari r =0 sampai r= takhingga

3. Hukum Ampere

Misalkan di suatu ruang terdapat medan magnet ***B***. *Di dalam ruang tersebut kita buat sebuah lintasan tertutup S yang sembarang*



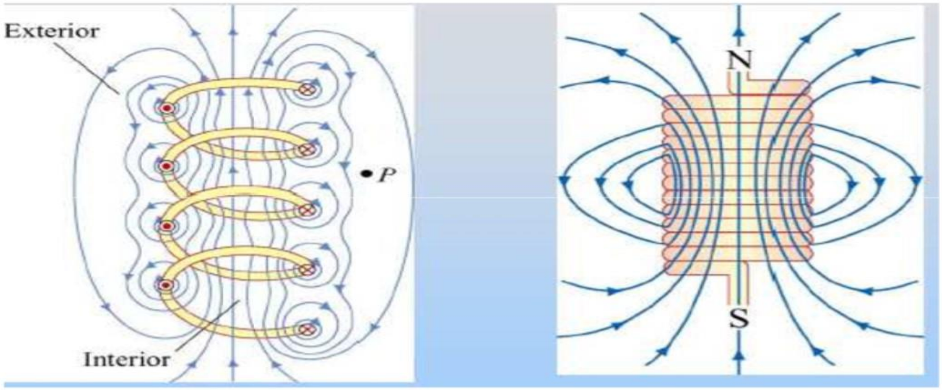
Integral perkalian titik ***B*** *danl* ***dl*** *dalam lintasan tertutup S memenuhi :*

$$\oint_S \vec{B} \cdot d\vec{l} = \mu_o \sum I$$ **HUKUM AMPERE**

$\sum I$ *= Jumlah arus total yang dilingkupi lintasan S*

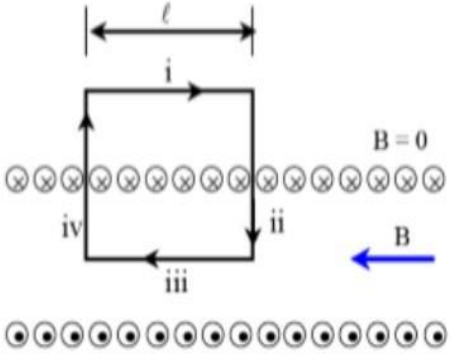
$\oint$ *= Integral harus dikerjakan pada lintasan tertutup*

Aplikasi Hukum Ampere



Gulungan renggang Gulungan rapat

Jika selenioda dibelah



Lintasan i : B = nol (berada di luar selenoida)

$$\oint_i \vec{B}.d\vec{l} = 0$$

Lintasan ii: Potongan yang ada di luar B = nol
Potongan yang ada di dalam
B tegak lurus lintasan

$$\oint_{ii} \vec{B}.d\vec{l} = \oint_{pot.luar} \vec{B}.d\vec{l} + \oint_{pot.dalam} \vec{B}.d\vec{l} = 0 + \oint_{pot.dalam} Bdl\cos 90 = 0$$

Lintasan iii : B sejajar lintasan

$$\oint_{iii} \vec{B}.d\vec{l} = \oint_{iii} Bdl\cos 0 = B\oint_{iii} dl = Bl$$

Lintasan iv: Potongan yang ada di luar B = nol
Potongan yang ada di dalam
B tegak lurus lintasan

$$\oint_{iv} \vec{B}.d\vec{l} = \oint_{pot.luar} \vec{B}.d\vec{l} + \oint_{pot.dalam} \vec{B}.d\vec{l} = 0 + \oint_{pot.dalam} Bdl\cos 90 = 0$$

Jumlah arus yang dilingkupi lintasan Ampere : $\sum I = nlI$

n = lilitan per satuan panjang

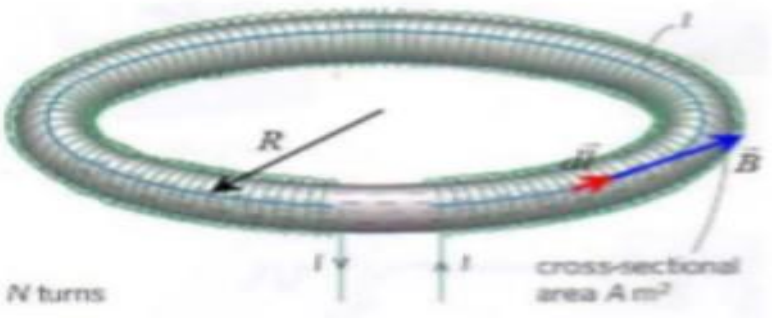
Maka :

$$\oint_S \vec{B}.d\vec{l} = \mu_o \sum I$$

$$Bl = \mu_o (nlI)$$

$$B = \mu_o In$$ **Kuat medan magnet dari selenoida**

Toroida



$$\vec{B} \,//\, d\vec{l}$$ Sudut θ = nol

$$\vec{B}.d\vec{l} = B\,dl\cos\theta = B\,dl\cos 0 = B\,dl$$

$$\oint_S \vec{B}.d\vec{l} = B\oint_S dl$$

$$= B\,x\,keliling\ lingkaran$$

$$= B\,x\,2\pi R$$

Jumlah arus yang dilingkupi lintasan Ampere : $\sum I = 2\pi RnI$

Maka :

$$\oint_S \vec{B}.d\vec{l} = \mu_o \sum I$$

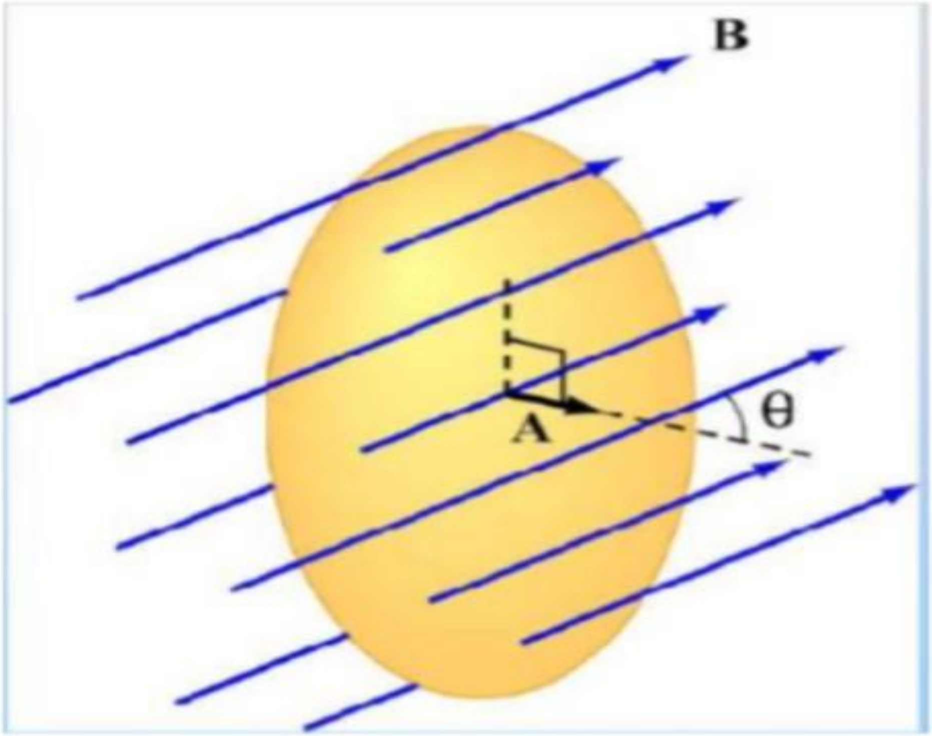
$$B(2\pi R) = \mu_o(2\pi RnI)$$

$$B = \mu_o In$$

Kuat medan magnet dari selenoida

4. Hukum Gauss Magnetik

Analog dengan Fluks Listrik (Hukum Gauss)



(1) **B** Uniform

$$\Phi_B = B_\perp A = BA\cos\theta = \vec{\mathbf{B}} \cdot \vec{\mathbf{A}}$$

(2) **B** Non-Uniform

$$\Phi_B = \int_S \vec{\mathbf{B}} \cdot d\vec{\mathbf{A}}$$

Animasi 8.2

5. Hukum Faraday

$$\mathcal{E} = -N \frac{d\Phi_B}{dt}$$

Perubahan fluks magnet menginduksi GGL

Cara untuk Menginduksi GGL

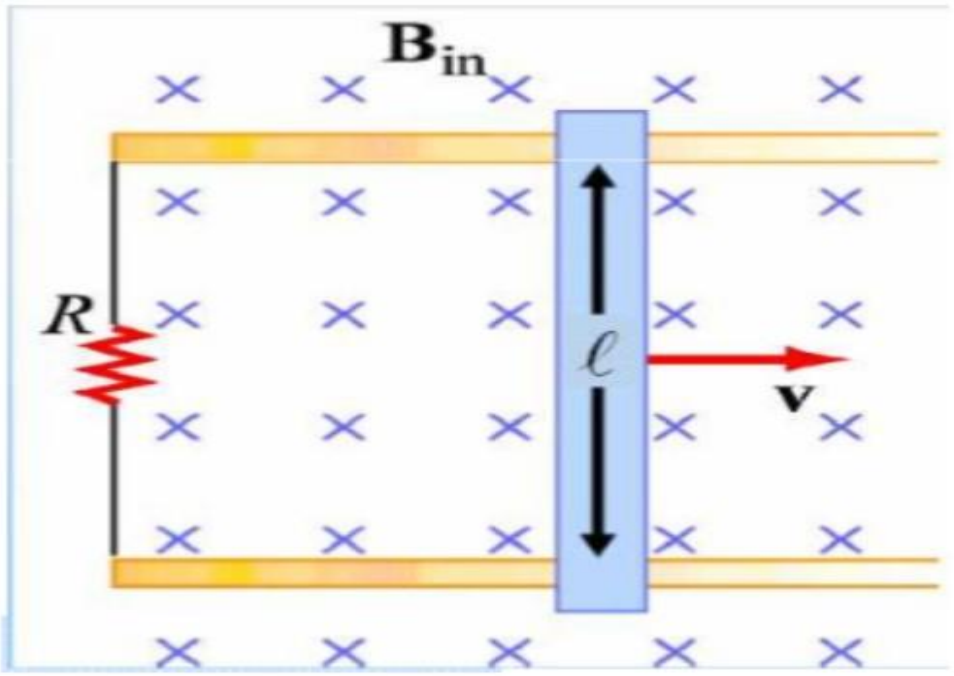
$$\mathcal{E} = -N \frac{d}{dt}\left(BA\cos\theta\right)$$

Kuantitas yang berubah terhadap waktu:

1. Besar B
2. Luas A yang dilingkupi loop
3. Sudut θ antara B dan normal loop

6. Hukum Faraday : Kawat Konduktor

Batang konduktor ditarik sepanjang dua rel konduktor dalam daerah bermedan magnet uniform B dengan kecepatan konstan **v**



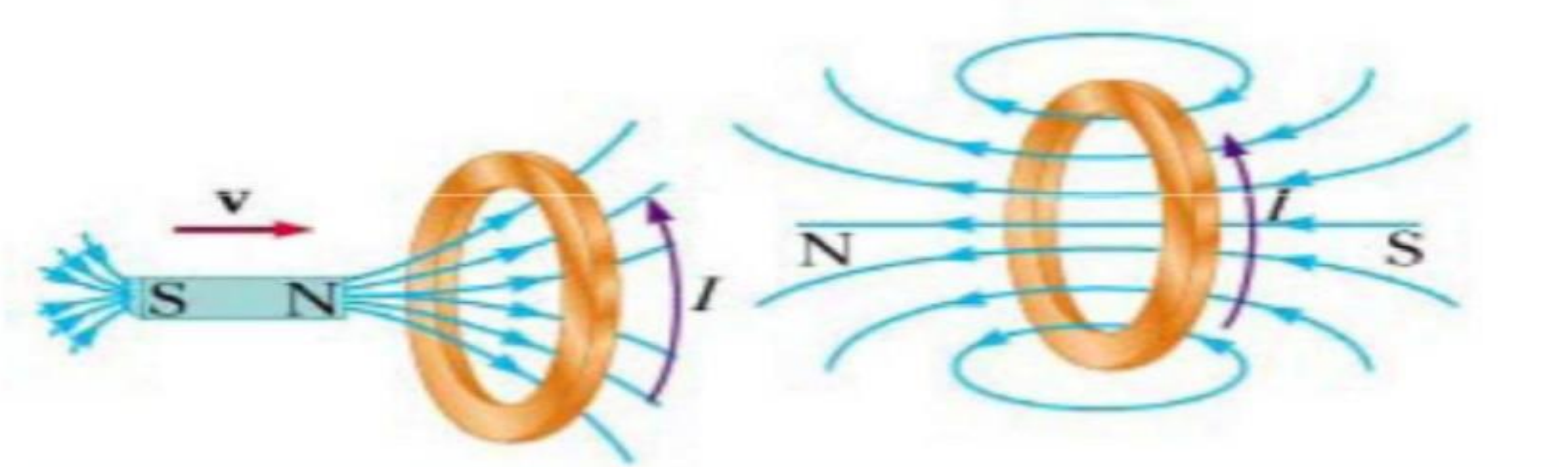
1. Arah arus induksi?
2. Arah resultan gaya?
3. Besar GGL?
4. Besar arus?
5. Daya eksternal yang harus disuplai agar batang bergerak dengan kecepatan konstan **v**?

Animasi 8.6

7. Hukum Lenz

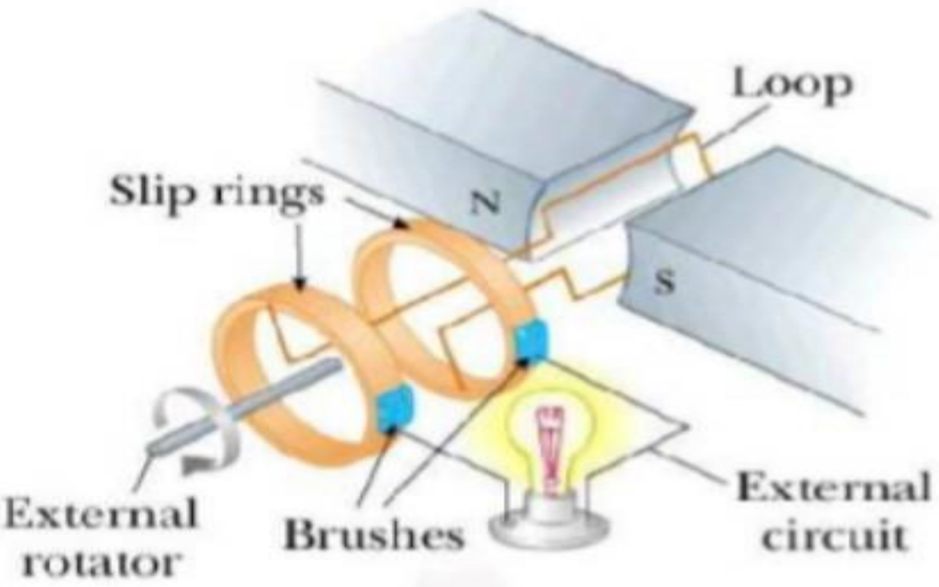
Tanda Negatif? Hukum Lenz

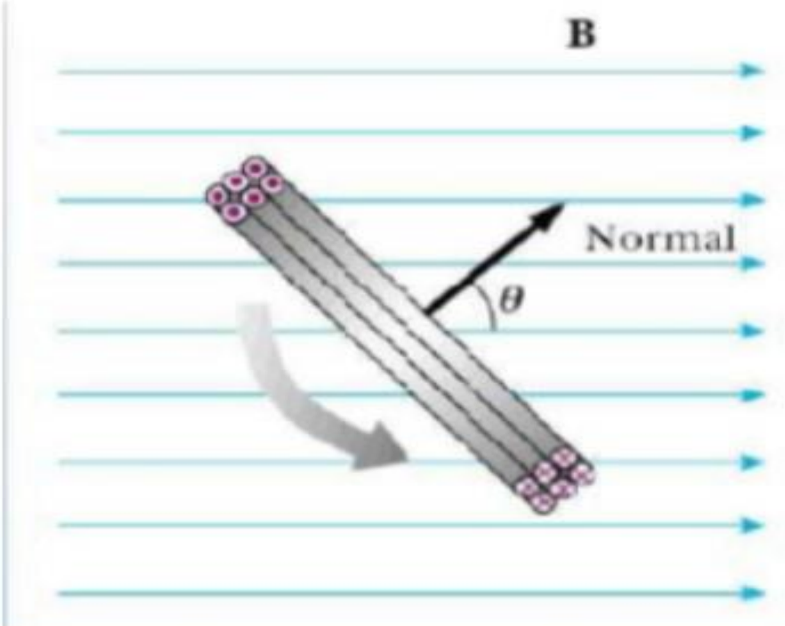
GGL Induksi yang muncul berarah melawan perubahan fluks yang menyebabkannya



Hukum Lenz: Arus induksi menghasilkan medan magnet yang melawan perubahan fluks magnet yang menghasilkan arus induksi tersebut

8. Generator

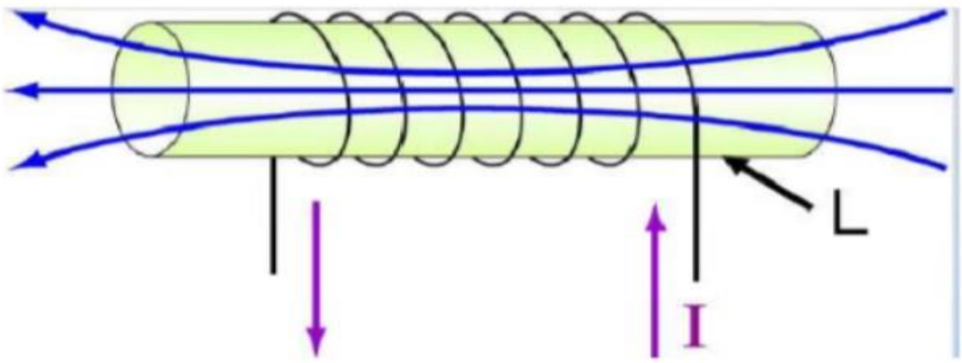




$$\Phi_B = BA\cos\theta = BA\cos\omega t$$

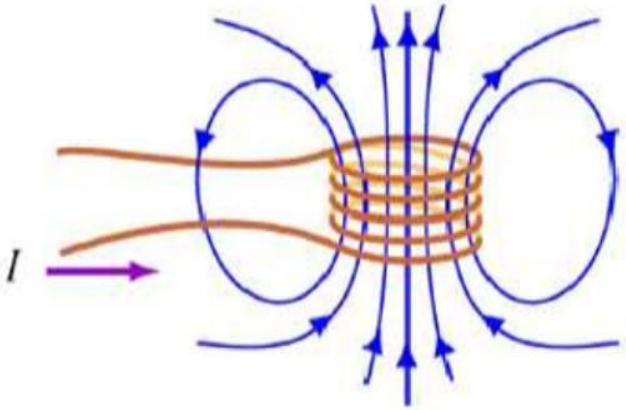
$$\varepsilon = -N\frac{d\Phi_B}{dt} = -NAB\frac{d}{dt}(\cos\omega t) = NAB\omega\sin\omega t$$

9. Indukstansi



$$\mathcal{E} = -L\frac{dI}{dt}$$

Induktansi Diri



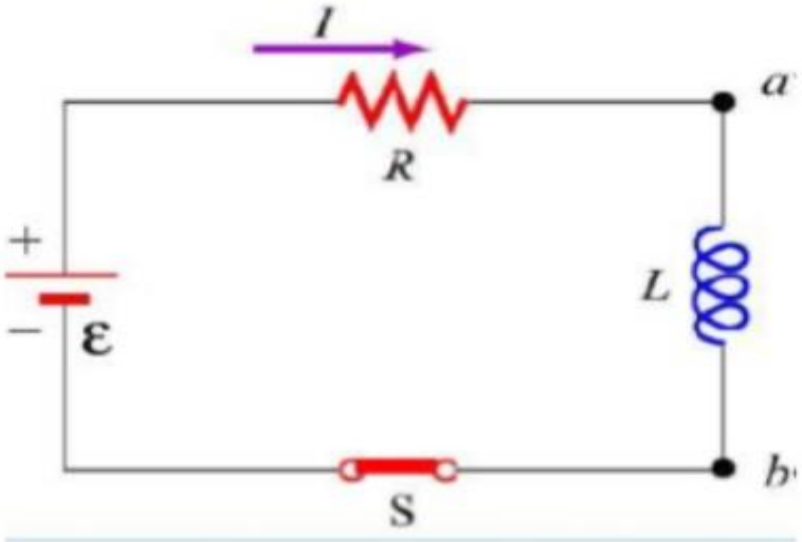
Sebuah koil dialiri arus listrik.
Arus konstan!
Arus berubah thd waktu!

$$\varepsilon_L = -N\frac{d\Phi_B}{dt} = -N\frac{d}{dt}\iint \vec{\mathbf{B}} \cdot d\vec{\mathbf{A}}$$

$$\varepsilon_L = -L\frac{dI}{dt} \qquad L = \frac{N\Phi_B}{I}$$

Secara fisis, Induktansi L adalah ukuran dari sebuah "resistansi" induktor untuk merubah arus; semakin besar L, semakin kecil laju perubahan arus.

Energi Tersimpan dalam Induktor



$$\mathcal{E} = +IR + L\frac{dI}{dt}$$

$$I\mathcal{E} = I^2R + LI\frac{dI}{dt}$$

$$I\mathcal{E} = I^2R + \frac{d}{dt}\left(\tfrac{1}{2}LI^2\right)$$

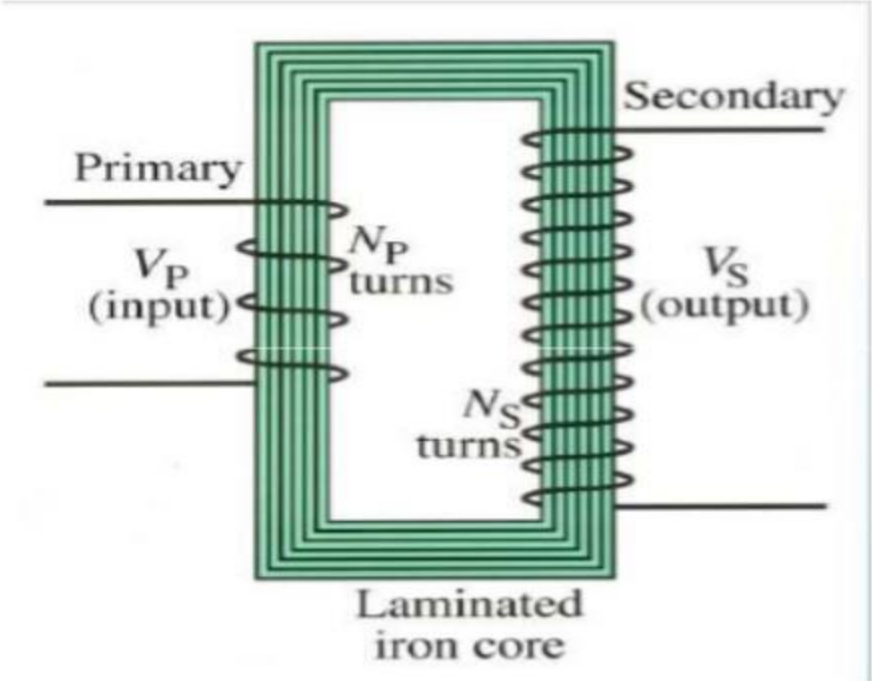
Batrei Penyuplai

Resistor Disipasi

Induktor Penyimpan

8. Trafo

Transformator



$$\mathcal{E}_p = N_p \frac{d\Phi_B}{dt}$$

$$\mathcal{E}_s = N_s \frac{d\Phi_B}{dt}$$

$$\frac{\mathcal{E}_s}{\mathcal{E}_p} = \frac{N_s}{N_p}$$

$N_s > N_p$: step-up transformator
$N_s < N_p$: step-down transformator

Persamaan Maxwell

Penghasil Medan Listrik:

$$\oiint_S \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} = \frac{Q_{in}}{\varepsilon_0}$$

Hukum Gauss

$$\oint_C \vec{\mathbf{E}} \cdot d\,\vec{\mathbf{s}} = -\frac{d\Phi_B}{dt}$$

Hukum Faraday

Penghasil Medan Magnet:

$$\oiint_S \vec{\mathbf{B}} \cdot d\vec{\mathbf{A}} = 0$$

Hukum Gauss Magnet

$$\oint_C \vec{\mathbf{B}} \cdot d\,\vec{\mathbf{s}} = \mu_0 I_{enc}$$

Hukum Ampere

Terima Kasih

Tugas : Soal dikerjakan per individu

EXERCISES AND PROBLEMS

Dikerjakan nomor 5 dan 6 saja

Exercises

Section 33.3 The Source of the Magnetic Field: Moving Charges

1. | Points 1 and 2 in FIGURE EX33.1 are the same distance from the wires as the point where $B = 2.0$ mT. What are the strength and direction of $\vec{B}$ at points 1 and 2?

FIGURE EX33.1

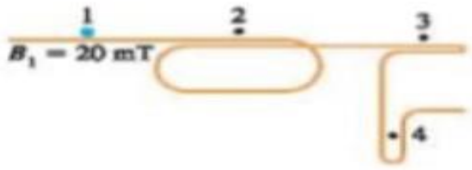


FIGURE EX33.2

2. | What is the magnetic field strength at points 2 to 4 in FIGURE EX33.2? Assume that the wires overlap closely and that points 1 to 4 are equally distant from the wires.
3. | A proton moves along the y-axis with $v_y = -1.0 \times 10^7$ m/s. As it passes the origin, what are the strength and direction of the magnetic field at the (x, y, z) positions (a) (1 cm, 0 cm, 0 cm), (b) (0 cm, 1 cm, 0 cm), and (c) (0 cm, −2 cm, 0 cm)?
4. | An electron moves along the z-axis with $v_z = 2.0 \times 10^7$ m/s. As it passes the origin, what are the strength and direction of the magnetic field at the (x, y, z) positions (a) (1 cm, 0 cm, 0 cm), (b) (0 cm, 0 cm, 1 cm), and (c) (0 cm, 1 cm, 1 cm)?
5. || What are the magnetic field strength and direction at the dot in FIGURE EX33.5?

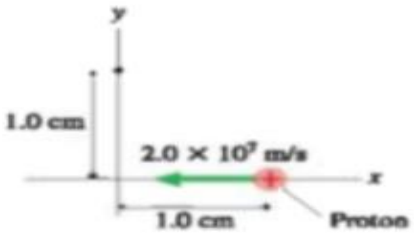


FIGURE EX33.5

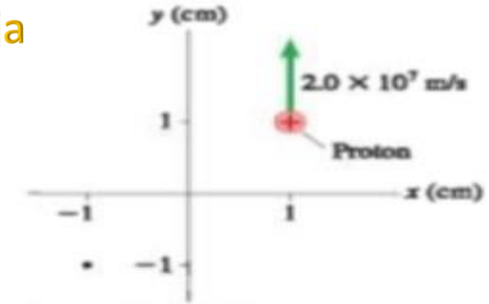


FIGURE EX33.6

6. || What are the magnetic field strength and direction at the dot in FIGURE EX33.6?
7. || A proton is passing the origin. The magnetic field at the (x, y, z) position (1 mm, 0 mm, 0 mm) is $1.0 \times 10^{-13}\,\hat{j}$ T. The field at (0 mm, 1 mm, 0 mm) is $-1.0 \times 10^{-13}\,\hat{i}$ T. What are the speed and direction of the proton?

Section 33.4 The Magnetic Field of a Current

8. | What currents are needed to generate the magnetic field strengths of Table 33.1 at a point 1.0 cm from a long, straight wire?
9. | At what distances from a very thin, straight wire carrying a 10 A current would the magnetic field strengths of Table 33.1 be generated?
10. || At what distance on the axis of a current loop is the magnetic field half the strength of the field at the center of the loop? Give your answer as a multiple of R.

Tugas : Soal dikerjakan per individu

Dikerjakan nomor 12, 13, 14, 46, 47, dan 48 (semua)

12. | A wire carries current I into the junction shown in FIGURE EX33.12. What is the magnetic field at the dot?

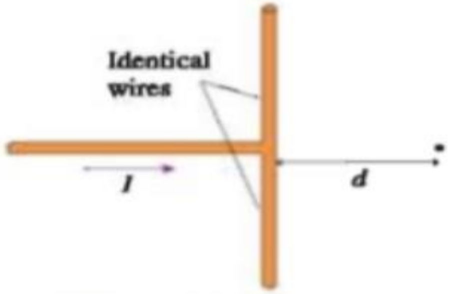


FIGURE EX33.12

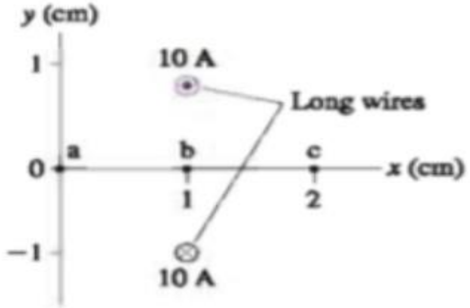


FIGURE EX33.13

13. || What is the magnetic field $\vec{B}$ at points a to c in FIGURE EX33.13? Give your answer in component form.

14. || What are the magnetic field strength and direction at points a to c in FIGURE EX33.14?

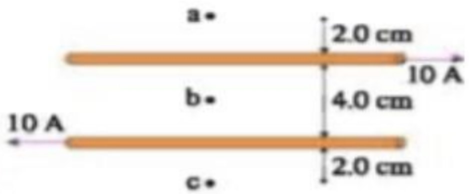


FIGURE EX33.14

46. || a. Find an expression for the magnetic field at the center (point P) of the circular arc in FIGURE P33.46.
   b. Does your result agree with the magnetic field of a current loop when $\theta = 2\pi$?

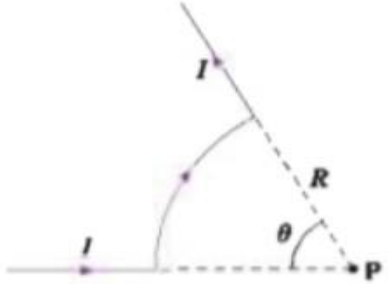


FIGURE P33.46

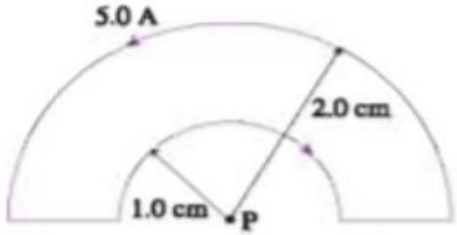


FIGURE P33.47

47. || What are the strength and direction of the magnetic field at point P in FIGURE P33.47?

48. || What is the magnetic field at the center of the loop in FIGURE P33.48?

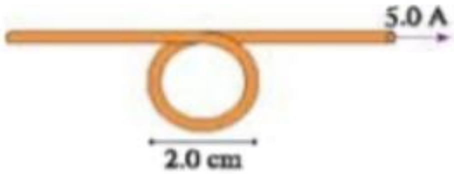


FIGURE P33.48