3.

$$I = \frac{\mathcal{E}}{R} = \frac{N}{R}\frac{d\phi}{dt}$$

$$I = \frac{120}{5.3}\frac{d}{dt}\left(\mu_0 n i_{Sol} A_{Sol}\right)$$

$$I = \frac{120}{5.3}\left(\mu_0 n A_{Sol}\right)\frac{di_{Sol}}{dt}, \text{ where } \frac{di_{Sol}}{dt} = \frac{2i_0}{t}$$

$$I = \frac{120}{5.3}\left(4\pi \times 10^{-7}\right)(22000)\left(\pi(.016)^2\right)\left(\frac{2(1.5)}{.05}\right)$$

$$I = 30 \text{ mA}$$

7.

a) $\phi = 6t^2 + 7t$

$$E = -\frac{d\phi}{dt} = -12t - 7$$

$@\, t = 2\,\text{sec},\ E = -31 \times 10^{-3}\ \text{volts}$

b) Want ϕ into page, so current in R must be right to left

11.

a) $\mathcal{E} = -N\dfrac{d\phi}{dt}$

$$\phi = \oint B \circ dA = \int B\, dA \cos\Theta$$

What is ϕ at any time t?

$$\phi = B\cos\Theta \int dA = abB\cos\Theta$$

If loop rotates at constant rate ν, $\Theta = 2\pi\nu t$

$$\frac{d\phi}{dt} = \frac{d}{dt}\left(abB\cos(2\pi\nu t)\right) = abB\frac{d}{dt}\left(\cos(2\pi\nu t)\right)$$

$$\frac{d\phi}{dt} = -2\pi\nu abB\sin(2\pi\nu t)$$

$$\mathcal{E} = -N\frac{d\phi}{dt} = \left[2\pi\nu NabB\right]\sin(2\pi\nu t)$$

$$\mathcal{E} = \mathcal{E}_0 \sin(2\pi\nu t)$$

b) $\mathcal{E}_0 = 150$ volts, $B = .5T$

$$2\pi Nab = \frac{\mathcal{E}_0}{\nu B} = \frac{150}{60(.5)} = 5m^2$$

Any loop with $Nab = \dfrac{5}{2\pi}$ will work.

13.

$$i = \frac{dq}{dt} = \frac{\mathcal{E}}{R} = \frac{1}{R}\frac{d\phi}{dt}$$

ϕ = BA and A is constant

$$\therefore \frac{dq}{dt} = \frac{1}{R}\frac{d(BA)}{dt} = \frac{A}{R}\frac{dB}{dt}$$

$$dq = \frac{A}{R}dB = (100\,\text{turns})\left(\frac{.0012}{13\Omega}\right)\left(3.2\frac{Wb}{m^2}\right)$$

$$dq = 29 \times 10^{-2}$$

units?

$$\frac{m^2}{ohms}\left(\frac{newton}{amp \cdot m}\right) = \frac{n \cdot m}{\left(\frac{volt}{amp}\right)amp} = \frac{joule}{volt}$$

$$= \frac{joule}{\left(\frac{joule}{coulomb}\right)} = coulomb$$

23. From far away, the field may be taken as equal to B on the axis.

a) $B = \dfrac{\mu_0 i R^2}{2x^3}$

Flux through small loop:

$$\phi = B(\pi r^2) = \frac{\mu_0 i R^2\,\pi r^2}{2x^3}$$

b) $E = \dfrac{d\phi}{dt} = \dfrac{1}{2}\mu_0 i R^2\,\pi r^2\,\dfrac{dx^{-3}}{dt}$

$$\frac{dx^{-3}}{dt} = -3x^{-4}\frac{dx}{dt} = -\frac{3v}{x^4}$$

$$E = \frac{3}{2}\mu_0 i R^2\,\pi r^2\,\frac{v}{x^4}$$

c) Flux is decreasing - so must drive a current around small loop in the same direction as in big loop.

27.

Flux thru strip?

$\phi = BA$

$d\phi = B(Ldy) = 4t^2 yLdy$

$\phi = \int d\phi = \int_0^L 4t^2 yLdy$

$\phi = 4t^2 L \int_0^L y\,dy = 4t^2 L\left(\frac{1}{2}y^2\Big|_0^L\right)$

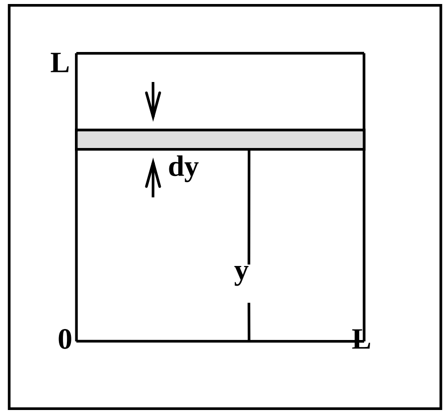
$\phi = 2t^2 L^3$

$\mathcal{E} = \frac{d\phi}{dt} = 4L^3 t$

$\mathcal{E}(t = 2.5) = 4(.02)^3 (2.5) = 8 \times 10^{-5}$ **volts**

Flux is coming out of page and increasing.

$\therefore$ **A clockwise current.**



28.

a) B for a long wire = $\frac{\mu_0 i}{2\pi r}$

$$\phi = \int B\,dA = \int \frac{\mu_0 i}{2\pi r} a\,dr$$

$$\phi = \frac{\mu_0 ia}{2\pi}\int_{r-\frac{b}{2}}^{r+\frac{b}{2}} \frac{dr}{r} = \frac{\mu_0 ia}{2\pi}\ln\left(\frac{r+\frac{b}{2}}{r-\frac{b}{2}}\right)$$

b) $i = \frac{\mathcal{E}}{R} = \frac{1}{R}\frac{d\phi}{dt}$

$$i = \frac{1}{R}\frac{d}{dt}\left[\frac{\mu_0 ia}{2\pi}\ln\left(\frac{r+\frac{b}{2}}{r-\frac{b}{2}}\right)\right] = \frac{\mu_0 ia}{2\pi R}\frac{d}{dt}\ln\left(\frac{r+\frac{b}{2}}{r-\frac{b}{2}}\right)$$

Use the quotient and chain rule, substitute $v = \frac{dr}{dt}$

$$i = \frac{\mu_0 ia}{2\pi R}\left(\frac{r-\frac{b}{2}}{r+\frac{b}{2}}\right)\frac{d}{dt}\left(\frac{r+\frac{b}{2}}{r-\frac{b}{2}}\right) = \frac{\mu_0 ia}{2\pi R}\left(\frac{r-\frac{b}{2}}{r+\frac{b}{2}}\right)\left(\frac{\left(r-\frac{b}{2}\right)\frac{dr}{dt}-\left(r+\frac{b}{2}\right)\frac{dr}{dt}}{\left(r-\frac{b}{2}\right)^2}\right)$$

$$i = \frac{\mu_0 ia}{2\pi R}\left(\frac{r-\frac{b}{2}}{r+\frac{b}{2}}\right)\left(\frac{-bv}{\left(r-\frac{b}{2}\right)^2}\right) = -\frac{\mu_0 iabv}{2\pi R\left(r+\frac{b}{2}\right)\left(r-\frac{b}{2}\right)} = -\frac{\mu_0 iabv}{2\pi R\left(r^2-\left(\frac{b}{2}\right)^2\right)}$$

$$i = -\frac{2\mu_0 iabv}{\pi R\left(4r^2-b^2\right)}$$

31.

a) $\mathcal{E} = BLv = (.35T)(.25m)\left(.55\frac{m}{sec}\right)$

$\mathcal{E} = 48.1\,mV$

b) $i = \frac{\mathcal{E}}{R} = \frac{48.1\,mV}{18\,\Omega} = 2.67\,mA$

c) $P = i^2R = \left(2.67\times10^{-3}\right)^2(18) = 1.28\times10^{-4}$ watts

35.

a) $\mathcal{E} = BLv = (1.2)(0.1)(5) = .6 \text{ volts}$

b) $i = \frac{V}{R} = \frac{.6}{.4} = 1.5 \text{ amps}$

c) Thermal energy $= i^2R = (1.5)^2(.4) = .9 \text{ watts}$

d) External force:

$F = iL \times B$

$F = 1.5(0.1)(1.2) = .18 \text{ newtons}$

e) $P = Fv = .18\,n\left(5\frac{m}{sec}\right) = .9 \text{ watts}$

Same answer as part c).

37.

a) @ $r = .022 \text{ meters}$

$$\frac{dB}{dt} = 6.5\frac{mT}{sec}$$

$$\int E \circ ds = -\frac{d\phi}{dt} = A\frac{dB}{dt}$$

$$E(2\pi r) = \pi r^2 \frac{dB}{dt}$$

$$E = \frac{r}{2}\frac{dB}{dt} = \frac{.022m}{2}\left(6.5 \times 10^{-3}\right) = 71.5\frac{\mu V}{m}$$

b) @ $r = .082 \text{ meters, i.e., } r > R$

so entire flux passes thru path.

$$E(2\pi r) = -\pi R^2 \frac{dB}{dt}$$

$$E = \frac{R^2}{2r}\frac{dB}{dt} = \frac{(.06)^2}{2(.082)}\left(6.5 \times 10^{-3}\right)$$

$$E = 143\frac{\mu V}{m}$$

40.

$$N\phi = Li$$

$$400\phi = 8\times10^{-3}\,H\left(5\times10^{-3}\,A\right)$$

$$\phi = 1\times10^{-7}\ \text{volt}\cdot\text{sec}$$

$$\text{units? Weber} = \frac{\text{newton}\cdot\text{meter}}{\text{amp}}$$

$$= \text{newton}\cdot\text{meter}\,\frac{\text{second}}{\text{coulomb}} = \text{joule}\,\frac{\text{second}}{\text{coulomb}}$$

$$= \frac{\text{joule}}{\text{coulomb}}\,\text{second} = \text{volt}\cdot\text{second}$$

44.

$$L = -\frac{\mathcal{E}}{\left(\frac{di}{dt}\right)}$$

$$12H = \frac{-60}{\left(\frac{di}{dt}\right)}$$

$$\text{Let } \frac{di}{dt} = 5\,\frac{\text{amps}}{\text{sec}}$$

48.

a) $\mathcal{E}_1 = -L_1\frac{dI_1}{dt},\ \mathcal{E}_2 = -L_2\frac{dI_2}{dt}$

$\mathcal{E}_1 = \mathcal{E}_2$ for parallel circuits

$$L_{Eq} = -\frac{\mathcal{E}}{\left(\frac{dI}{dt}\right)}$$

$$\frac{dI}{dt} = \frac{dI_1}{dt} + \frac{dI_2}{dt} = \frac{\mathcal{E}}{L_1} + \frac{\mathcal{E}}{L_2}$$

$$\therefore \frac{1}{L_{Eq}} = \frac{1}{L_1} + \frac{1}{L_2}$$

b) If they are close, ones changing B – field will induce a current on the other.

c) $\frac{1}{L_{Eq}} = \sum_i \frac{1}{L_i}$ for all i.

53.

a) $I = \frac{E}{R}\left(1 - \exp\left[-\frac{R}{L}t\right]\right)$

$$\text{Final value} = \frac{14V}{1200\Omega} = .0117$$

80% of this is .0093

$$.0093 = .0117\left(1 - \exp\left[-\frac{1200}{6.3\times 10^{-6}}t\right]\right)$$

$$.798 = 1 - \exp\left[-.190\times 10^{9}t\right]$$

$$\ln(.202) = -.190\times 10^{9}t$$

$$t = 8.42\times 10^{-9}\text{ sec}$$

b) One time constant is when $t = \frac{L}{R}$.

$$I = \frac{E}{R}\left(1 - \exp\left[-\frac{R}{L}t\right]\right) = \frac{E}{R}\left(1 - e^{-1}\right)$$

$$I = \frac{14}{1200}(1 - .368) = 7.4\,\text{mA}$$

55.

$$I = \frac{\mathcal{E}}{R}\left(1 - \exp\left[-\frac{R}{L}t\right]\right)$$

$$.999 = 1.00\left(1 - \exp\left[-\frac{R}{L}t\right]\right)$$

$$.001 = \exp\left[-\frac{R}{L}t\right]$$

$$\ln(.001) = -\frac{R}{L}t$$

$$-6.9 = -\frac{t}{\tau_L}$$

or $t = 6.9\tau_L$

61.

$$i = \frac{\mathcal{E}}{R}\left(1 - \exp\left[-\frac{R}{L}t\right]\right)$$

@ $t = .005,\ i = .002$

$$.002 = \frac{50}{10000}\left(1 - \exp\left[-\frac{R}{L}(.005)\right]\right)$$

$$.4 = 1 - \exp\left[-.005\frac{R}{L}\right]$$

$$\ln(.6) = -.005\frac{R}{L}$$

$$\frac{-.005}{\ln(.6)} = \frac{L}{R} = \frac{L}{10000}$$

$$L = 97.9\,H$$

$$U = \frac{1}{2}Li^2 = .5(97.9)(.002)^2$$

$$U = 1.96 \times 10^{-4}\ \text{joules}$$

62.

a) $U = \frac{1}{2}LI^2$

$$\frac{dU_B}{dt} = Li\frac{di}{dt}$$

need $i = ?$

$$i = \frac{\mathcal{E}}{R}\left(1 - \exp\left[-\frac{R}{L}t\right]\right) = \frac{100}{10}\left(1 - \exp\left[-\frac{10}{2}(.1)\right]\right)$$

$$i = 3.9\ \text{amps}$$

$$\frac{di}{dt} = \frac{\mathcal{E}}{L}\exp\left[-\frac{R}{L}t\right] = \frac{100}{10}\exp\left[-\frac{10}{2}(.1)\right] = 30.3\frac{\text{amps}}{\text{sec}}$$

$$\frac{dU_B}{dt} = (2\,H)(3.9\,A)\left(30.3\frac{\text{amps}}{\text{sec}}\right) = 236\ \text{watts}$$

b) Heat only appears in R.

$$\text{Heat} = i^2R = (3.9)^2(10) = 152\ \text{watts}$$

c) Battery's power $= \mathcal{E}i = 100(3.9) = 390$ watts

Check: Sum of parts a) & b) $= 236 + 152 = 388 =$ part c).

72.

$$N\phi = Li$$

$$\text{a) } \phi_{12} = \frac{Li}{N} = \frac{(25\times10^{-3})(6\times10^{-3})}{100} = 1.5\times10^{-6}\,\text{Wb}$$

$$\mathcal{E} = -L\frac{di}{dt} = -25\times10^{-3}(4) = 100\text{mV}$$

$$\text{b) } M = \frac{N_2\phi_{21}}{i_1}$$

$$3\times10^{-3} = \frac{200\phi_{21}}{6\times10^{-3}}$$

$$\phi_{21} = \frac{18\times10^{-6}}{200} = .9\times10^{-6}\,\text{Wb}$$

$$\mathcal{E} = -M\frac{di}{dt} = 3\times10^{-3}(4) = 12\text{mV}$$

75.

$$M = \frac{N\phi}{I}, \text{ and } \phi = BA$$

The problem here is that B of a long straight wire $B = \frac{\mu_0 I}{2\pi r}$ **varies with r.**

Start with $d\phi = d(BA)$.

$$\int d\phi = \int \frac{l\mu_0 I}{2\pi r}dr$$

$$\phi = \frac{l\mu_0 I}{2\pi}\int_a^{a+b}\frac{dr}{r} = \frac{l\mu_0 I}{2\pi}\left[\ln(a+b) - \ln(a)\right]$$

$$\phi = \frac{l\mu_0 I}{2\pi}\ln\left(\frac{a+b}{a}\right)$$

$$M = \frac{N\phi}{I} = \frac{N}{I}\frac{l\mu_0 I}{2\pi}\ln\left(\frac{a+b}{a}\right)$$

$$M = \frac{l\mu_0 N}{2\pi}\ln\left(\frac{a+b}{a}\right)$$

76.

$$M = \frac{N_2 \phi_{21}}{I}$$

flux = BA

$$B = \mu_0 nI,\ A = \pi R^2$$

$$M = \frac{NBA}{I} = \frac{N(\mu_0 nI)(\pi R^2)}{I}$$

$$M = N\mu_0 n\pi R^2$$

79.

Condition I

a)Switch just closed. $i_2 = 0$

$$i_1 = \frac{E}{R_1} = \frac{10V}{5\Omega} = 2amps$$

b) $i_2 = 0$

c) $i = i_1 + i_2 = 2amps$

d)Potential across R_2?

$$V_2 = i_2 R_2 = 0(R_2) = 0$$

e)Potential across L?

Use loop theorem (clockwise, page 676).

$$V_L + V_{R2} + V_{R1} = 0$$

$$V_L + 0 + 2A(5\Omega) = 0$$

$$V_L = -10volts$$

f) $V_L = -L\frac{di_2}{dt}$

$$10 = 5\frac{di_2}{dt} \Rightarrow \frac{di_2}{dt} = 2\frac{amps}{sec}$$

Condition II, After a long time the inductor has no effect.

a) $i_1 = \frac{E}{R_1} = \frac{10}{5} = 2amps$

b) $i_2 = \frac{E}{R_2} = \frac{10}{10} = 1amp$

c) $i = i_1 + i_2 = 3amps$

d) $V_2 = i_2 R_2 = 1(10) = 10volts$

e) $V_L = -L\frac{di_2}{dt} = -L(0) = 0$

f) $\frac{di_2}{dt} = \frac{E_L}{L} = 0$

85.

A changing B-field produces an E-field.

$$\frac{dB}{dt} = 10^{-2}\,\frac{T}{sec}$$

$$\int E \circ ds = -\frac{d\phi}{dt} = -A\,\frac{dB}{dt}$$

$$E(2\pi r) = \pi r^2\,\frac{dB}{dt}$$

$$E = \frac{r}{2}\frac{dB}{dt} = \frac{.05}{2}\left(10^{-2}\,\frac{T}{sec}\right) = 2.5 \times 10^{-4} \quad @\, r = .05m$$

$$F = ma = Eq \Rightarrow a = \frac{Eq}{m}$$

$$a = \frac{\left(2.5 \times 10^{-4}\right)\left(1.6 \times 10^{-19}\right)}{9.11 \times 10^{-31}} = 4.4 \times 10^{7}\,\frac{m}{sec^2}$$

a) E – field $\leftarrow$, so e^- $\rightarrow$

b) r = 0 $\Rightarrow$ E = 0, so e^- remains stationary.

c) E – field $\rightarrow$, so e^- $\leftarrow$

Reasoning: B down is decreasing.

Lenz's Law: Want B down increasing.

Use the right – hand rule.

89.

$$I = \frac{\mathcal{E}}{R} = \frac{100}{10} = 10\,\text{amps}$$

$$U = \frac{1}{2}LI^2$$

$$U = .5(2)(10)^2 = 100\ \text{joules}$$

94.

a) $L = \mu_0 n^2 lA$

answer calls for $\frac{L}{l} = \mu_0 n^2 A$

$$\frac{L}{l} = \left(4\pi \times 10^{7}\right)\ 10^4 \frac{turns}{m}\ ^2 \pi(.016m)^2$$

$$\frac{L}{l} = .101H$$

b) $E = L\ \frac{di}{dt}$

$$E = .101 \times\ 13\frac{amps}{sec}\ = 1.31 volts$$

97.

$$\frac{di}{dt} = \frac{\mathcal{E}}{L}\exp\left[-\frac{Rt}{L}\right]$$

$$\frac{di}{dt} = \frac{45}{.05}\exp\left[-\frac{180}{.05}(.0012)\right]$$

$$\frac{di}{dt} = 900e^{-4.32} = 12\frac{amps}{sec}$$