78. ‖ The switch in FIGURE P34.78 has been open for a long time. It is closed at $t = 0$ s.

a. What is the current through the battery immediately after the switch is closed?

b. What is the current through the battery after the switch has been closed a long time?

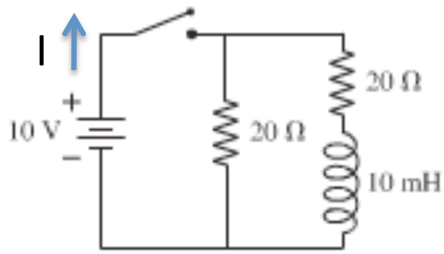
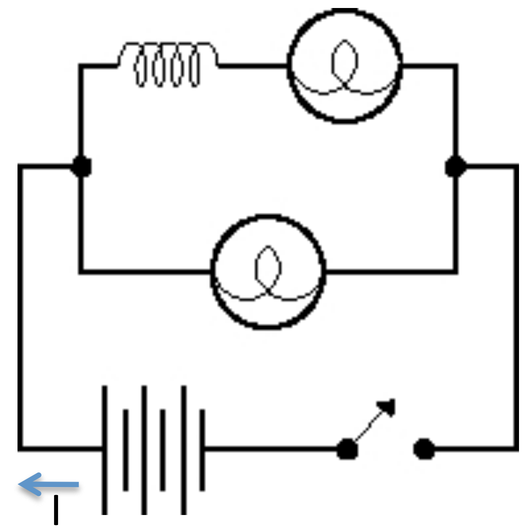


FIGURE P34.78



From Summary 5 as well as Supplement #7

Important Equations

Self Inductance, L: $L = \frac{\Phi_B}{I}$

EMF Induced by Inductor: $\mathcal{E} = -L\frac{dI}{dt}$

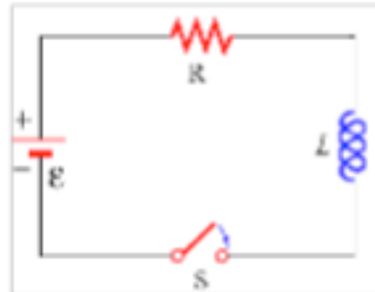
Energy stored in Inductor: $U = \frac{1}{2}LI^2$

Energy Density in B Field: $u_B = \frac{B^2}{2\mu_0}$

Exponential Decay: $Value = Value_{initial}e^{-t/\tau}$

Exponential "Decay Upwards": $Value = Value_{final}\left(1-e^{-t/\tau}\right)$

Simple RL Time Constant: $\tau = L/R$



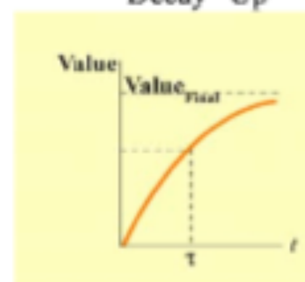
$$IR - \mathcal{E}_{battery} = -L\frac{dI}{dt}$$

which is first order linear differential equation with constant coefficients. The solution to this differential equation

$$I(t) = \frac{\mathcal{E}_{battery}}{R}(1-e^{-t/\tau})$$

shows that the current increases exponentially from its initial value of zero to a final constant value of $\mathcal{E}_{battery}/R$. The rate at which this change happens is dictated by the "time constant" τ, which for this circuit is given by $\tau = L/R$.

"Decay" Up



When the switch is closed there will not be any current flowing initially (t=0)in the circuit. As time goes it will increase and eventually reaches constant current level I=ε/R. The inductor plays no role since V_L=-L(dI/dt)=0

78. || The switch in FIGURE P34.78 has been open for a long time. It is closed at $t = 0$ s.

a. What is the current through the battery immediately after the switch is closed?

b. What is the current through the battery after the switch has been closed a long time?

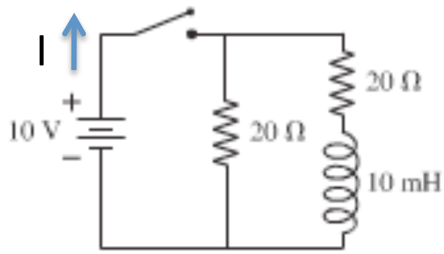
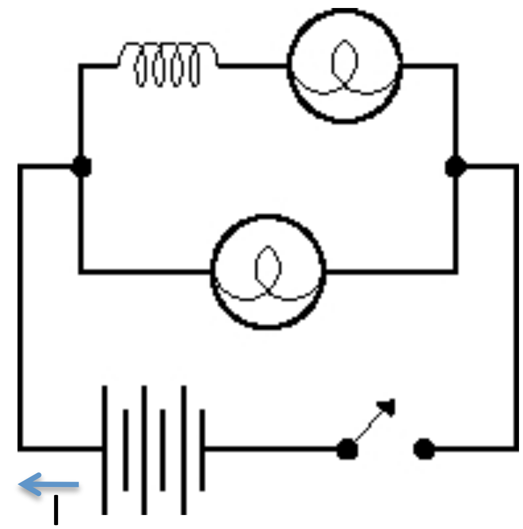


FIGURE P34.78



a. When the switc just opens no current through inductor. It operates as an open switch. I=10V/20 Ω=.5 A
b. After a long time current constant. V_L=-L(dI/dt)=0. Inductor is a closed switch. $1/R=1/R_1+1/R_2$. R=10 Ω. I=1 A.

12. a. Can you tell which of the inductors in FIGURE Q34.12 has the larger current through it? If so, which one? Explain.

b. Can you tell through which inductor the current is changing more rapidly? If so, which one? Explain

c. If the current enters the inductor from the bottom, can you tell if the current is increasing, decreasing, or staying the same? If so, which? Explain.

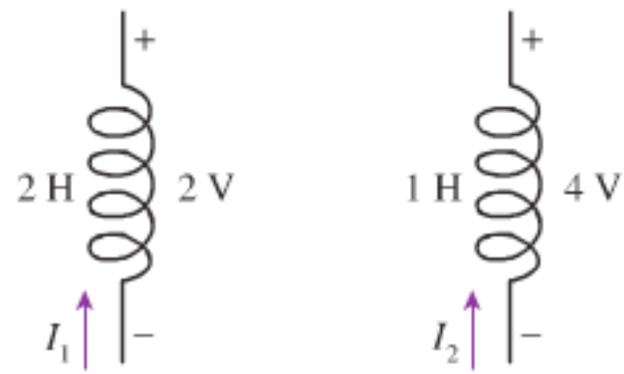


FIGURE Q34.12

a. Inductor produces effects only for dI/dt different than zero. No.
b. Yes right hand DV/L=abs(dI/dt)
c. Yes. Current decreasing. If dI/dt<0 then DV>0 . Potential increases in the direction of current.

82. A rectangular metal loop with 0.050 Ω resistance is placed next to one wire of the *RC* circuit shown in FIGURE CP34.82. The capacitor is charged to 20 V with the polarity shown, then the switch is closed at $t = 0$ s.

a. What is the direction of current in the loop for $t > 0$ s?

b. What is the current in the loop at $t = 5.0\ \mu s$? Assume that only the circuit wire next to the loop is close enough to produce a significant magnetic field.

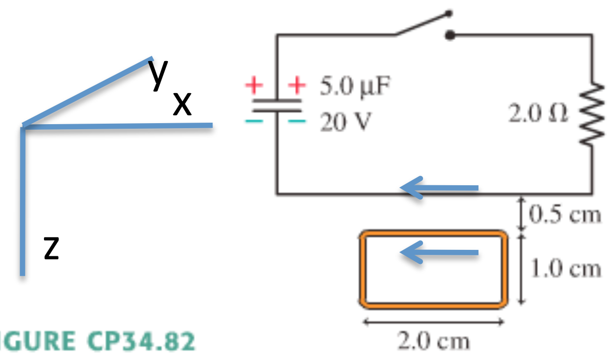
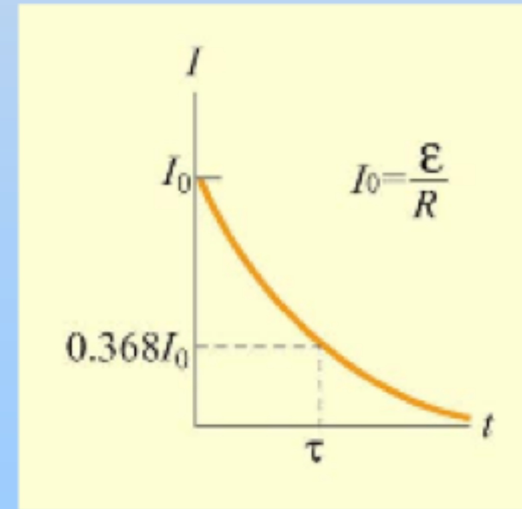


FIGURE CP34.82



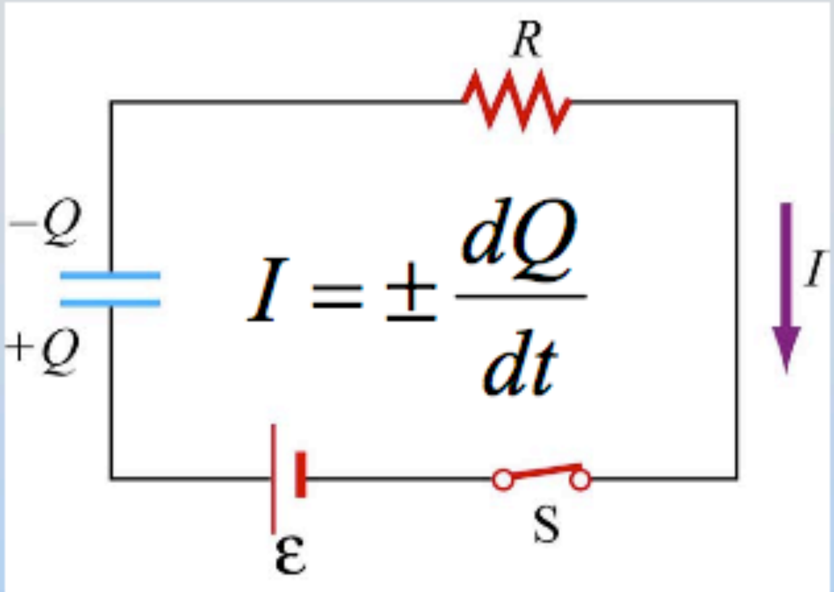
$$I = \frac{dQ}{dt} = \frac{\mathcal{E}}{R} e^{-t/RC}$$

P23 - 1

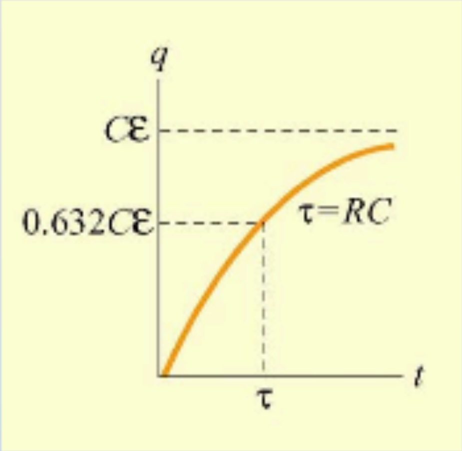
a. Current in the circuit is I$(-\hat{i})$ It creates a magnetic field through the circuit in the negative y-direction (out of the paper) . Current is decreasing with time induced current in the loop tries to increase magnetic flux and creates a B-field in the negative y-direction. So current in the loop flows counterclockwise.

From Supplement # 7

(Dis)Charging A Capacitor

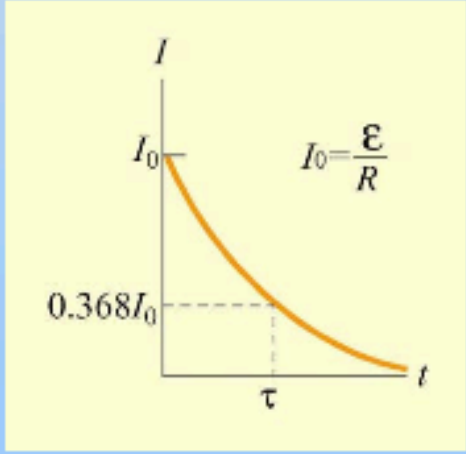


$$I = \pm \frac{dQ}{dt}$$



$$Q = C\mathcal{E}\left(1 - e^{-t/RC}\right)$$

$$\sum_i \Delta V_i = \varepsilon - \frac{Q}{C} - IR = 0$$



Q_{final} $\quad$ τ

$$\boxed{C\mathcal{E}} - Q - \boxed{RC}\frac{dQ}{dt} = 0$$

$$I = \frac{dQ}{dt} = \frac{\mathcal{E}}{R} e^{-t/RC}$$

82. A rectangular metal loop with 0.050 Ω resistance is placed next to one wire of the RC circuit shown in FIGURE CP34.82. The capacitor is charged to 20 V with the polarity shown, then the switch is closed at $t = 0$ s.

a. What is the direction of current in the loop for $t > 0$ s?

b. What is the current in the loop at $t = 5.0\ \mu s$? Assume that only the circuit wire next to the loop is close enough to produce a significant magnetic field.

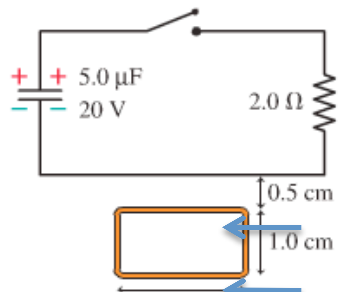
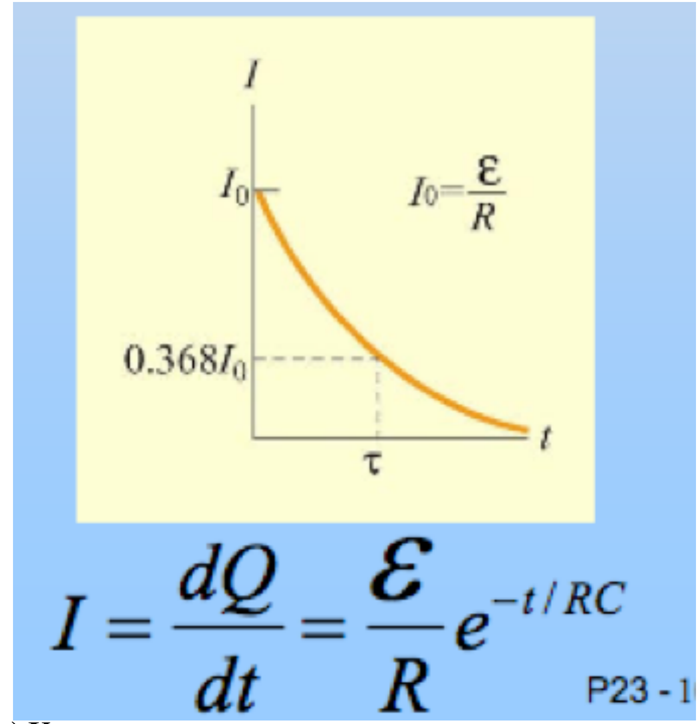


FIGURE CP34.82



$$\Phi = \int_0^b dx \int_c^{c+a} dz B(z) = b \int_c^{c+a} dz \frac{\mu_0}{2\pi z} I(t) = \frac{\mu_0 I(t)}{2\pi} b \int_c^{c+a} \frac{dz}{z} = I(t) \frac{\mu_0 b}{2\pi} \ln\left(\frac{c+a}{c}\right) \equiv I(t) K$$

$$K \equiv \frac{\mu_0 b}{2\pi} \ln\left(\frac{c+a}{c}\right) = 4.4 \times 10^{-9} \frac{Tm^2}{A}$$

$$I(t) = I(t=0)\exp(-t/\tau)$$

$$\tau = 1/RC = 10^{-5} \text{ sec}$$

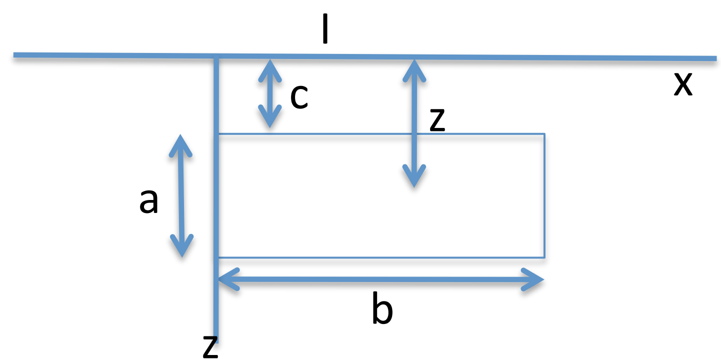
$$I(t=0) = V/R = 10A$$

$$t = 5 \times 10^{-6} \text{ sec}$$

$$\varepsilon = \left|\frac{d\Phi}{dt}\right| = \frac{K}{\tau} I(t=0)\exp(-t/\tau) = .267mV$$

$$I_{loop} = 5.3mA$$

For t->infinity emf->0



Example 34.5

83. The L-shaped conductor in FIGURE CP34.83 moves at 10 m/s across a stationary L-shaped conductor in a 0.10 T magnetic field. The two vertices overlap, so that the enclosed area is zero, at $t = 0$ s. The conductor has a resistance of 0.010 ohms *per meter*.

a. What is the direction of the induced current?

b. Find expressions for the induced emf and the induced current as functions of time.

c. Evaluate $\mathcal{E}$ and I at $t = 0.10$ s.

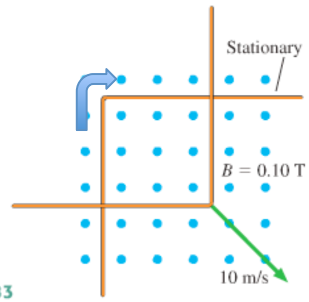


FIGURE CP34.83

a. B field out of the page. Flux increases with motion and time since the area expands. Induced current should prevent it (Lentz). Needs to create B into the page. Clockwise current flow.

b. $$\Phi = BA$$

$$\varepsilon = \left|\frac{d\Phi}{dt}\right| = B\frac{dA}{dt}$$

$$x = y = vt$$

$$A = xy = (vt)^2$$

$$\varepsilon = \left|\frac{d\Phi}{dt}\right| = 2Bv^2t$$

$$R = rl = r2vt$$

$$I = \frac{\varepsilon}{R} = \frac{Bv}{r}$$

I independent of time at 35 A

5. || Laboratory scientists have created the electric and magnetic fields shown in FIGURE EX35.5. These fields are also seen by scientists that zoom past in a rocket traveling in the x-direction at 1.0×10^6 m/s. According to the rocket scientists, what angle does the electric field make with the axis of the rocket?

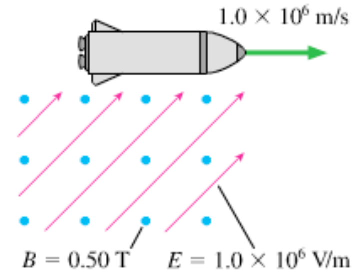


FIGURE EX35.5

Transform field from S to S'

$$\vec{V} = V\hat{i}$$

$$\vec{B} = B\hat{k}$$

$$\vec{E} = \frac{E}{\sqrt{2}}(\hat{i} + \hat{j})$$

$$\vec{E}' = \vec{E} + \vec{V} \times \vec{B}$$

$$\vec{E}' = \frac{E}{\sqrt{2}}(\hat{i} + \hat{j}) + BV(\hat{i} \times \hat{k}) = \frac{E}{\sqrt{2}}\hat{i} + (\frac{E}{\sqrt{2}} - BV)\hat{j}$$

$$\tan\theta = 1 - \frac{\sqrt{2}BV}{E}$$

$$\theta = \tan^{-1}(1 - \frac{\sqrt{2}BV}{E}) = 16.3 \text{ degrees above the x' axis}$$

34. || In FIGURE P35.34, a circular loop of radius r travels with speed v along a charged wire having linear charge density λ. The wire is at rest in the laboratory frame, and it passes through the center of the loop.

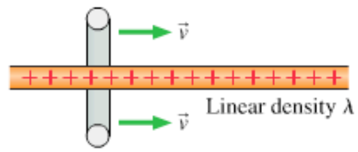
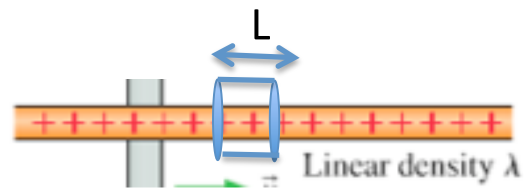


FIGURE P35.34

a. What are $\vec{E}$ and $\vec{B}$ at a point on the loop as measured by a scientist in the laboratory? Include both strength and direction.
b. What are the fields $\vec{E}'$ and $\vec{B}'$ at a point on the loop as measured by a scientist in the frame of the loop?
c. Show that an experimenter in the loop's frame sees a current $I = \lambda v$ passing through the center of the loop.
d. What electric and magnetic fields would an experimenter in the loop's frame calculate at distance r from the current of part c?
e. Show that your fields of parts b and d are the same.
f. If the loop is made of a conducting material, will it have an induced current? Explain.



a. Use gauss's law to compute E in S

$$2\pi r L E_r = Q/\varepsilon_o = \lambda L/\varepsilon_o$$

$$\vec{E} = \hat{r}(\lambda/2\pi\varepsilon_o r)$$

b. In S' frame

$$\vec{E}' = \vec{E} + \vec{v}\times\vec{B} = \vec{E} + 0$$

$$\vec{B}' = \vec{B} - \frac{1}{c^2}\vec{v}\times\vec{E} = -\frac{\lambda}{2\pi\varepsilon_o c^2 r}(\vec{v}\times\hat{r}) = \frac{\lambda}{2\pi\varepsilon_o c^2 r}\hat{\theta}(\text{int o pge at the top})$$

c. For a length L the charge is ΔQ=λL $\quad I = \Delta Q/\Delta t = \lambda(L/\Delta t) = \lambda v$

d.e. The electric field is the field due to the wire so $\quad B' = \frac{\mu_o I}{2\pi r} = \frac{\mu_o \lambda v}{2\pi r} = \frac{\mu_o \varepsilon_o \lambda v}{\varepsilon_o 2\pi r} = \frac{1}{\varepsilon_o c^2}\frac{\lambda v}{2\pi r}$

f. No since is E is perpendicular to the loop and no E-flux through the loop.

48. || In reading the instruction manual that came with your garage-door opener, you see that the transmitter unit in your car produces a 250 mW signal and that the receiver unit is supposed to respond to a radio wave of the correct frequency if the electric field amplitude exceeds 0.10 V/m. You wonder if this is really true. To find out, you put fresh batteries in the transmitter and start walking away from your garage while opening and closing the door. Your garage door finally fails to respond when you're 42 m away. Are the manufacturer's claims true?

$$I = P/A = P/4\pi r^2$$

$$I = \langle S \rangle = c\frac{\varepsilon_o E_o^2}{2}$$

$$E_o^2 = (P/4\pi r^2)/(c\frac{\varepsilon_o}{2}) = (2P/4\pi\varepsilon_o c r^2)$$

$$E_o = \sqrt{\alpha P/r^2} = \sqrt{\alpha P}/r$$

$$\alpha \equiv 2k_c/c = 2\times(9\times10^9/3\times10^8)(Nm^2\,\mathrm{sec}/C^2m) = 60Nm\,\mathrm{sec}/C^2$$

$$E_o(r = 42m) = \sqrt{(60\times.25)}/42 = .092\frac{V}{m}$$

The field drops as 1/r. Door opened earlier when field was .1 V/m.
Claims correct