Your Comments

I have a few questions: 1) Is the induced emf from the inductor, induced on itself or another wire going through it? 2) How is the voltage able to jump from 0 to some other value after the circuit switch has been opened to disconnect the battery? 3) Finally, I thought that the magnetic field could do no work, so how does it store energy, doesn't that mean it is doing work on the charges in the inductor? I don't know if I worded that right, but I hope you understand what I am asking.

this might be a stupid question but how is it possible for an inductor to have twice the voltage of a battery once it is disconnected from the battery?! where did this extra voltage come from?

Spring break 2013, more like one man one a lot of smart physics lectures and studying for physics. AND the right hand rule............

How are office hours going to be handled, what with spring break and all?

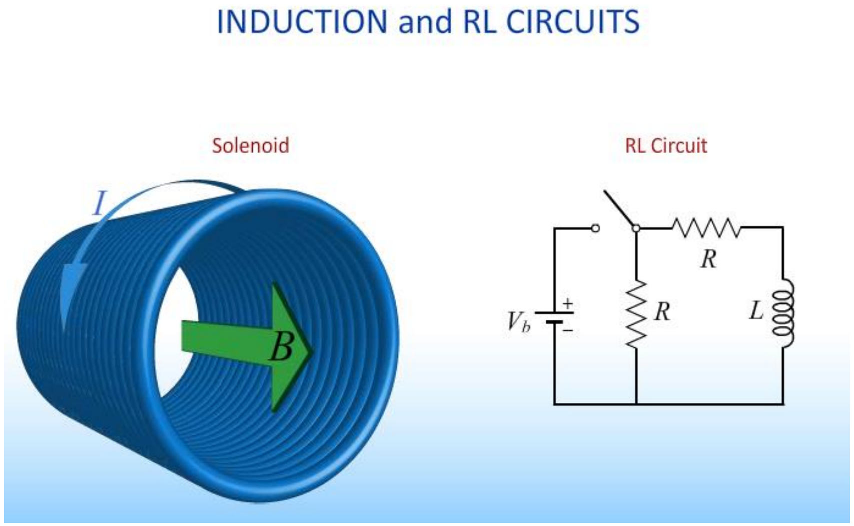
Seeing as it's pi day today, I'm trying to think of a clever and witty comment to make...but honestly all I can think about is how hungry I am and what I would give to just be eating some pie right now.

Physics 212
Lecture 18

Today’s Concepts:

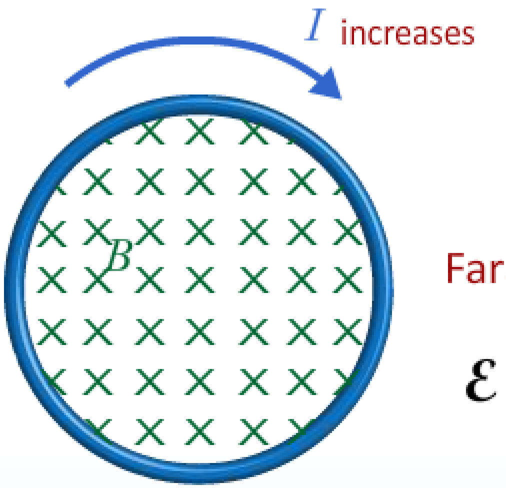
A) Induction

B) RL Circuits



Hour Exam 2 is October 31st
Lectures 9-18

From the Prelecture: Self Inductance



Self-Inductance

$$\boxed{L \equiv \frac{\Phi_B}{I}}$$

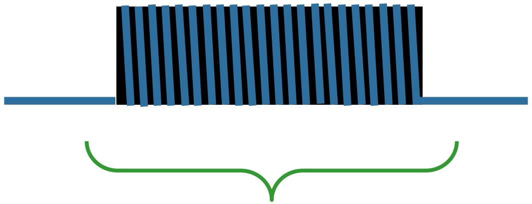
SI Unit

$$H = T\text{-}m^2/A$$

Faraday's Law

$$\mathcal{E} = -\frac{d\boxed{\Phi_B}}{dt} = -\frac{d(LI)}{dt} = -L\frac{dI}{dt}$$

Wrap a wire into a coil to make an “inductor”…

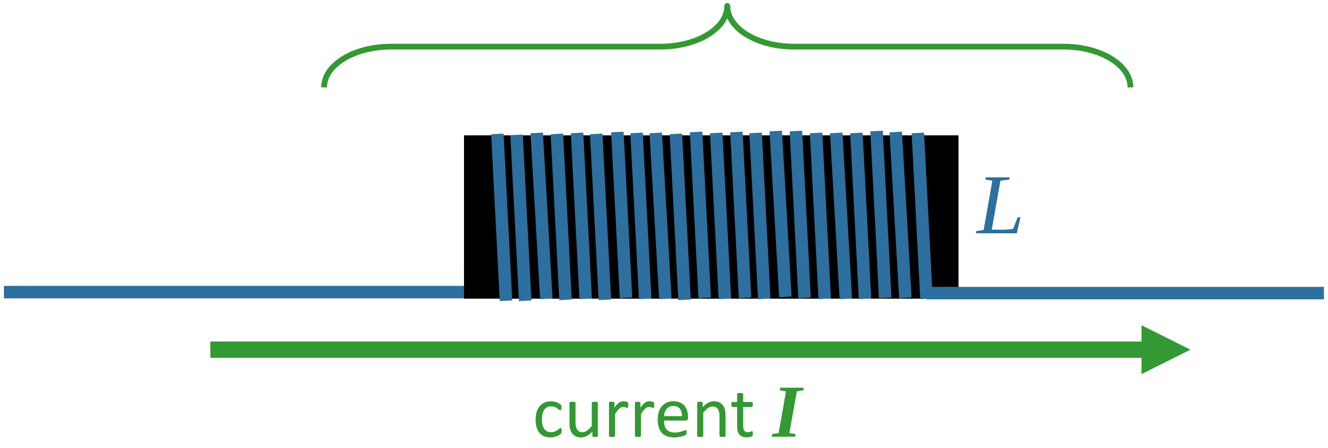


$$\mathcal{E} = -L\frac{dI}{dt}$$

What this really means:

emf induced across L tries to keep I constant.

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



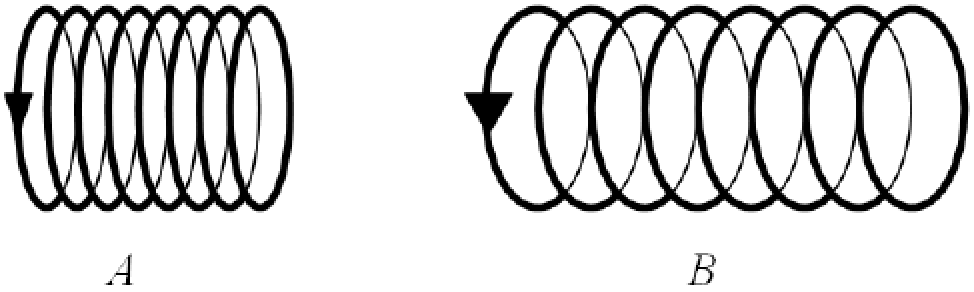
Inductors prevent discontinuous current changes!

It's like inertia!

CheckPoint 2

Two solenoids are made with the same cross sectional area and total number of turns. Inductor B is twice as long as inductor A

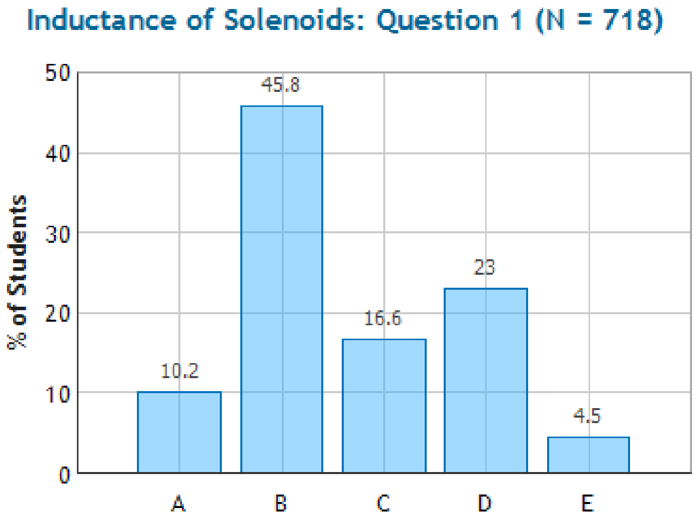
$$L_B = \mu_0 \underset{(1/2)^2}{\underset{\uparrow}{n^2}} \pi r^2 \underset{2}{\underset{\uparrow}{z}}$$



$$\longrightarrow \quad L_B = \tfrac{1}{2} L_A$$

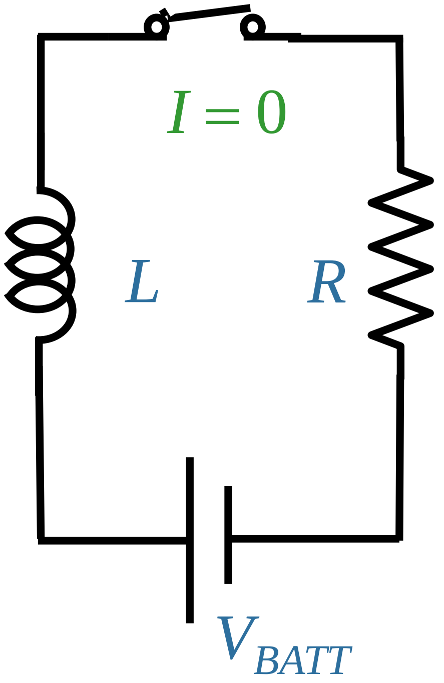
Compare the inductance of the two solenoids

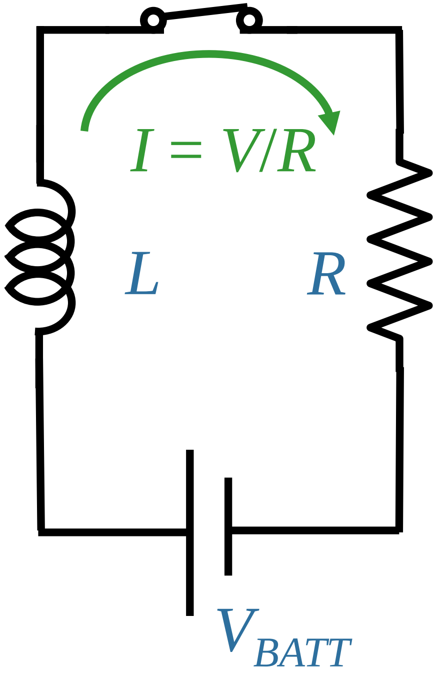
A) $L_A = 4\, L_B$
B) $\boxed{L_A = 2\, L_B}$
C) $L_A = L_B$
D) $L_A = (1/2)\, L_B$
E) $L_A = (1/4)\, L_B$

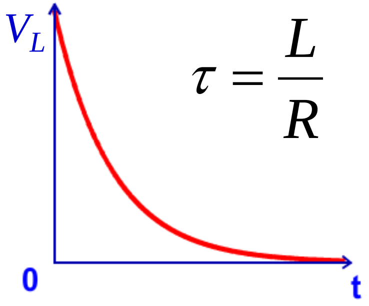


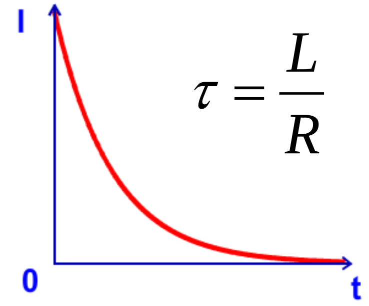
How to think about RL circuits Episode 1:

When no current is flowing initially:









At $t = 0$:

$I = 0$

$V_L = V_{BATT}$

$V_R = 0$

(L is like an open circuit)

At $t >> L/R$:

$V_L = 0$

$V_R = V_{BATT}$

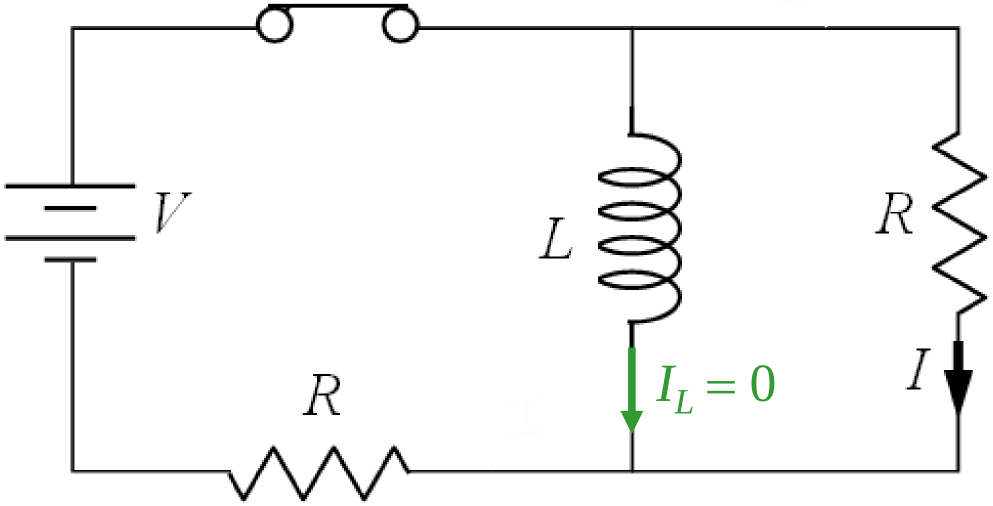
$I = V_{BATT}/R$

(L is like a wire)

CheckPoint 2a

In the circuit, the switch has been open for a long time, and the current is zero everywhere.

At time $t = 0$ the switch is closed.



What is the current I through the vertical resistor immediately after the switch is closed?

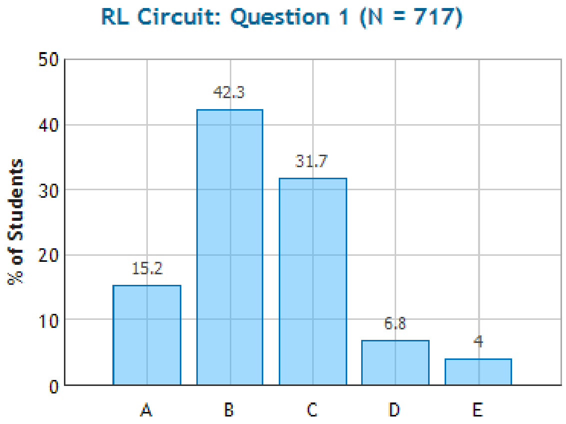
(+ is in the direction of the arrow)

A) $I = V/R$
[✓ B) $I = V/2R$]
C) $I = 0$
D) $I = -V/2R$
E) $I = -V/R$

Before: $I_L = 0$

After: $I_L = 0$

→ $I = +\,V/2R$


RL Circuit: Question 1 (N = 717)

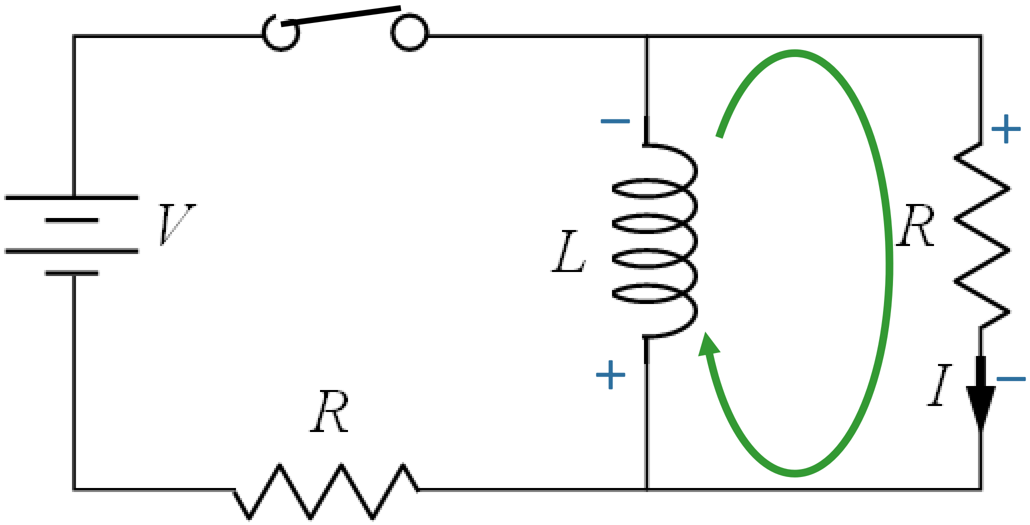
A	15.2
B	42.3
C	31.7
D	6.8
E	4

RL Circuit (Long Time)

What is the current I through the vertical resistor after the switch has been closed for a long time?

(+ is in the direction of the arrow)

A) $I = V/R$
B) $I = V/2R$
[✓ C) $I = 0$]
D) $I = -V/2R$
E) $I = -V/R$

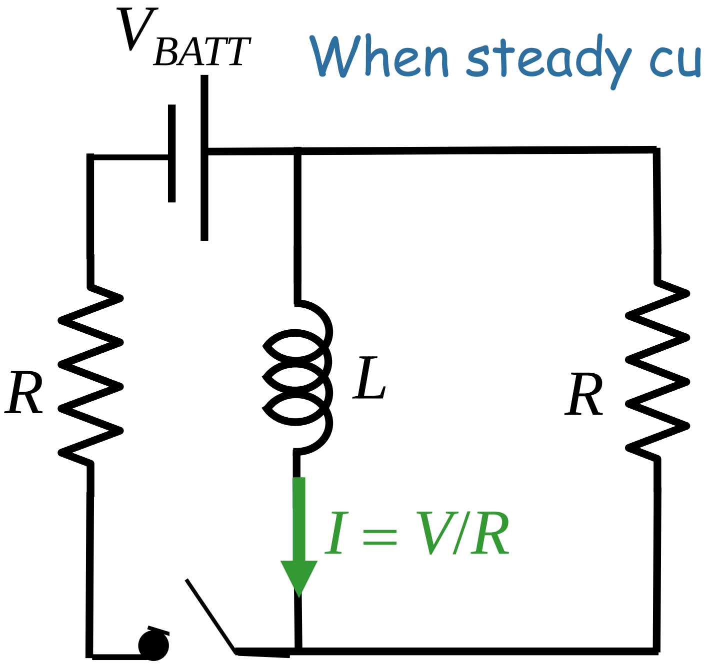


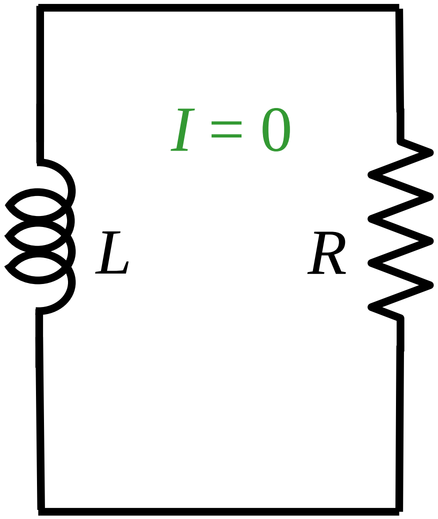
After a long time in any static circuit: $V_L = 0$

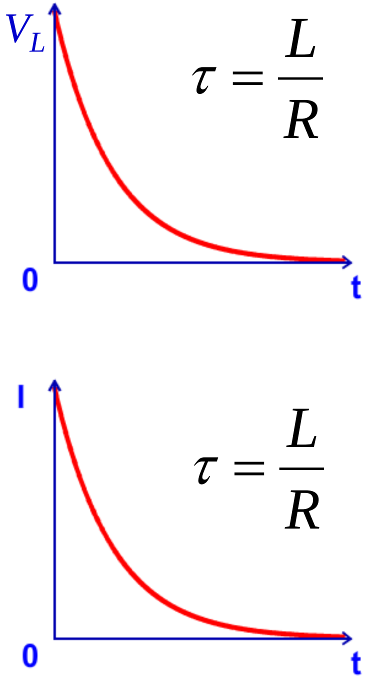
KVR:
$$V_L + IR = 0$$

How to Think about RL Circuits Episode 2:

When steady current is flowing initially: then switch is opened







At $t = 0$:

$I = V_{BATT}/R$

$V_R = IR$

$V_L = V_R$

At $t >> L/R$:

$I = 0$

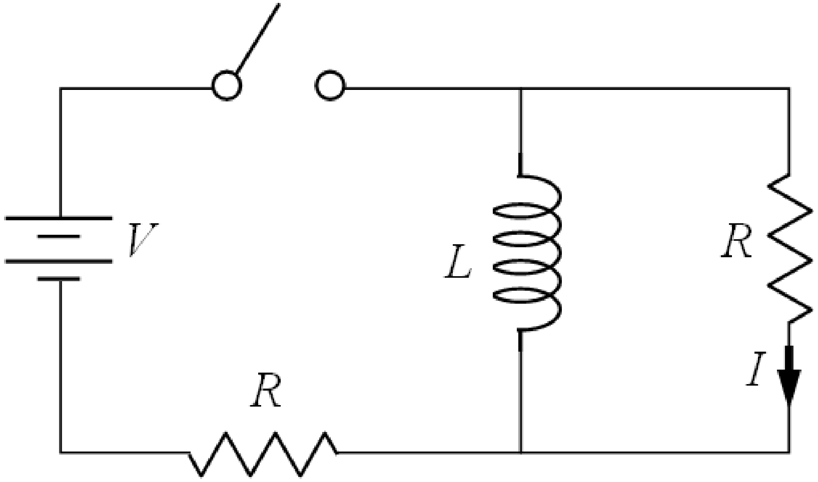
$V_L = 0$

$V_R = 0$

CheckPoint 2b

After a long time, the switch is opened, abruptly disconnecting the battery from the circuit.

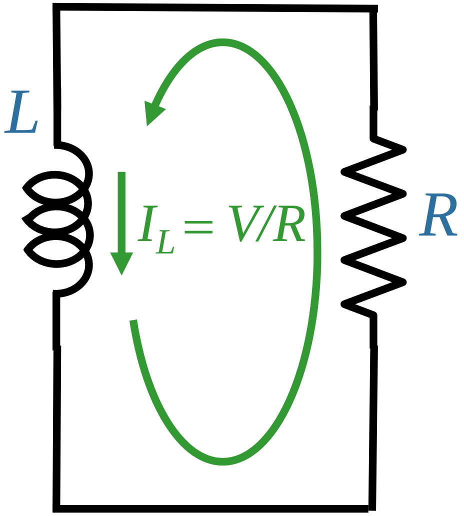
What is the current I through the vertical resistor immediately after the switch is opened?

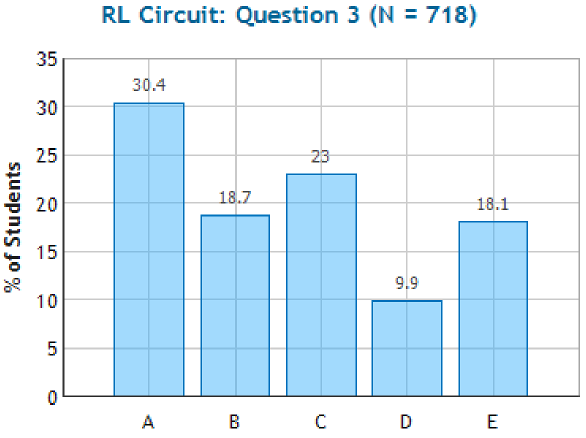


(+ is in the direction of the arrow)

A) $I = V/R$
B) $I = V/2R$
C) $I = 0$
D) $I = -V/2R$
E) $I = -V/R$

circuit when switch opened

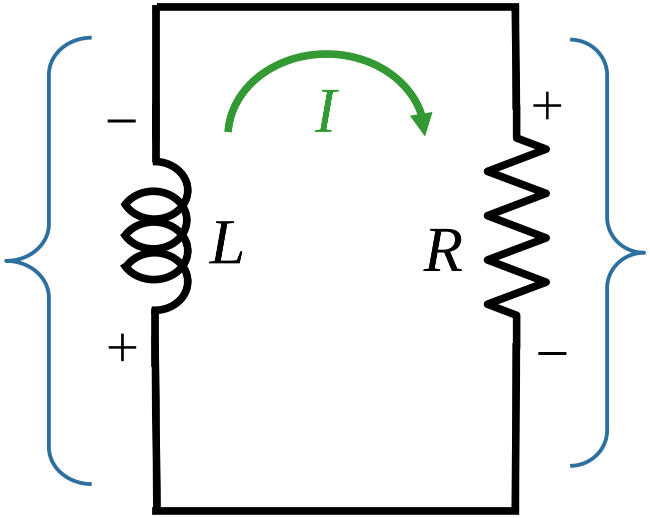




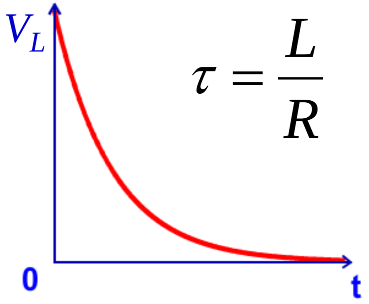
Current through inductor cannot change DISCONTINUOUSLY

Why is there Exponential Behavior?

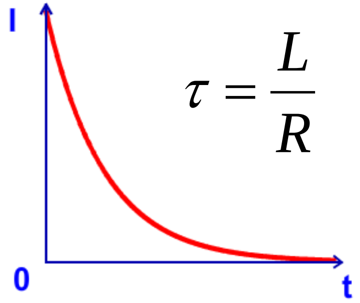
$$V = L\frac{dI}{dt}$$



$$V = IR$$



$$\tau = \frac{L}{R}$$

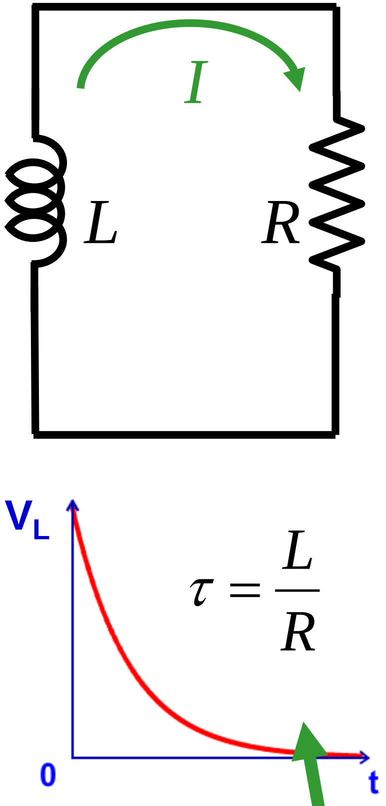


$$\tau = \frac{L}{R}$$

$$L\frac{dI}{dt} + IR = 0$$

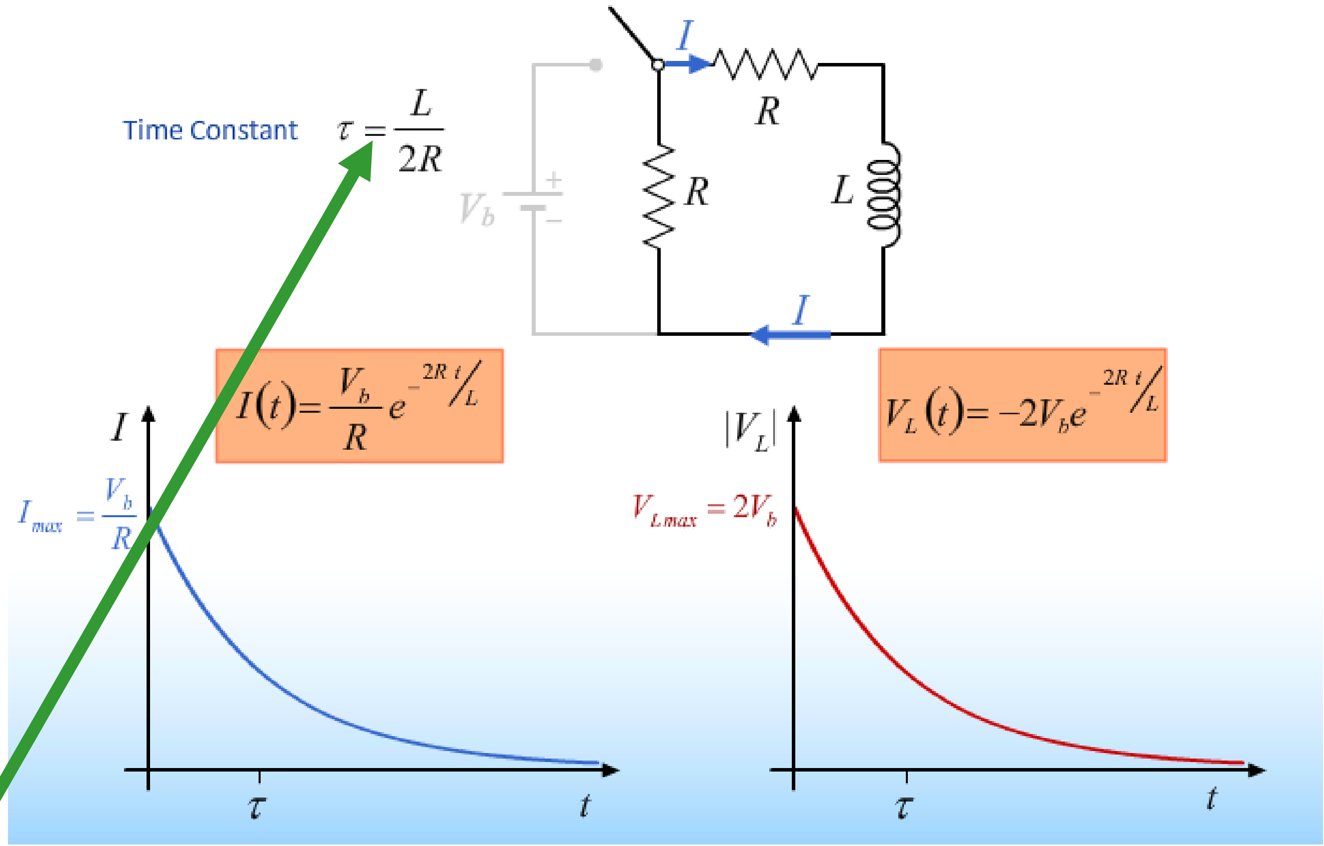
$$I(t) = I_0 e^{-tR/L} = I_0 e^{-t/\tau}$$

where $\tau = \frac{L}{R}$



$$\tau = \frac{L}{R}$$

Lecture:



Time Constant $\tau = \frac{L}{2R}$

$$I(t) = \frac{V_b}{R} e^{-2R\,t/L}$$

$$V_L(t) = -2V_b e^{-2R\,t/L}$$

$I_{max} = \frac{V_b}{R}$

$V_{L\,max} = 2V_b$

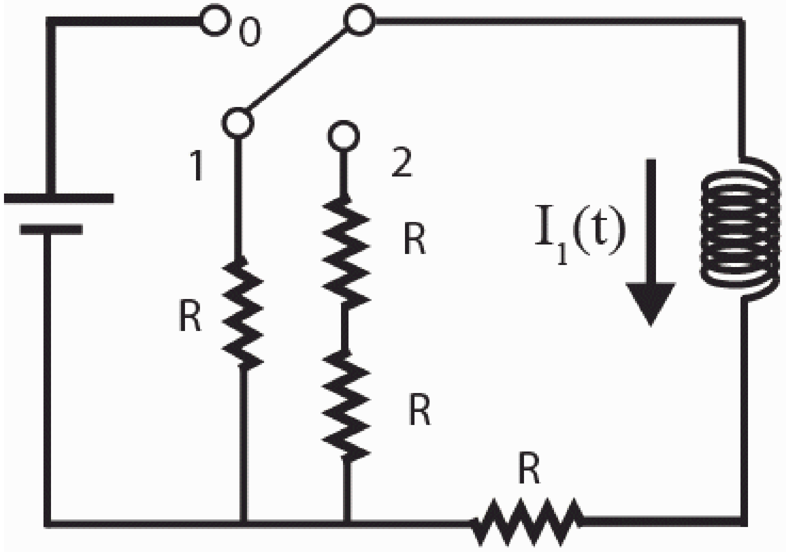
Prelecture:

Did we mess up?

No: The resistance is simply twice as big in one case.

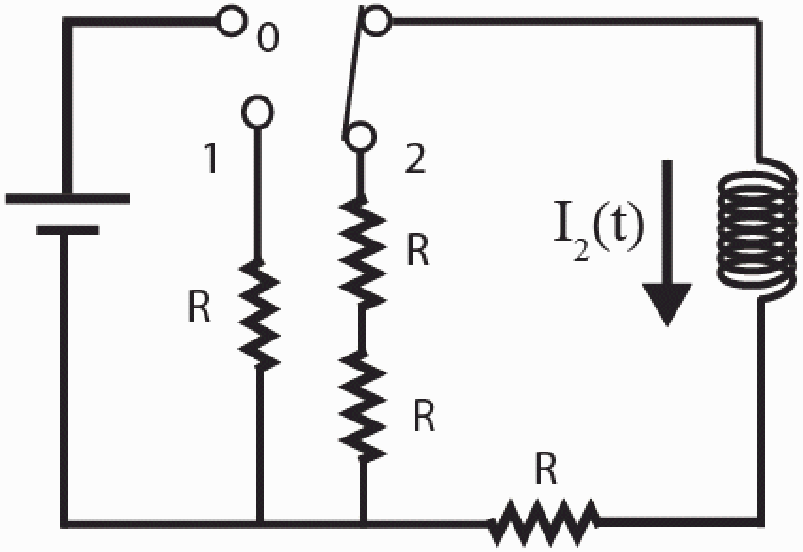
CheckPoint 3a

After long time at 0, moved to 1



Case 1

After long time at 0, moved to 2



Case 2

After switch moved, which case has larger time constant?

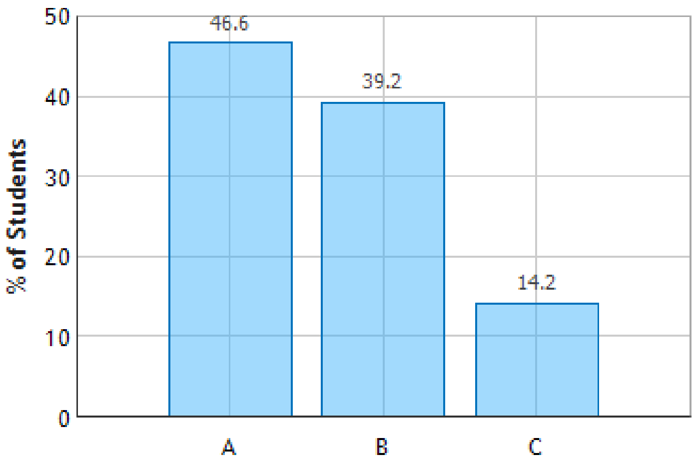
A) Case 1

B) Case 2

C) The same

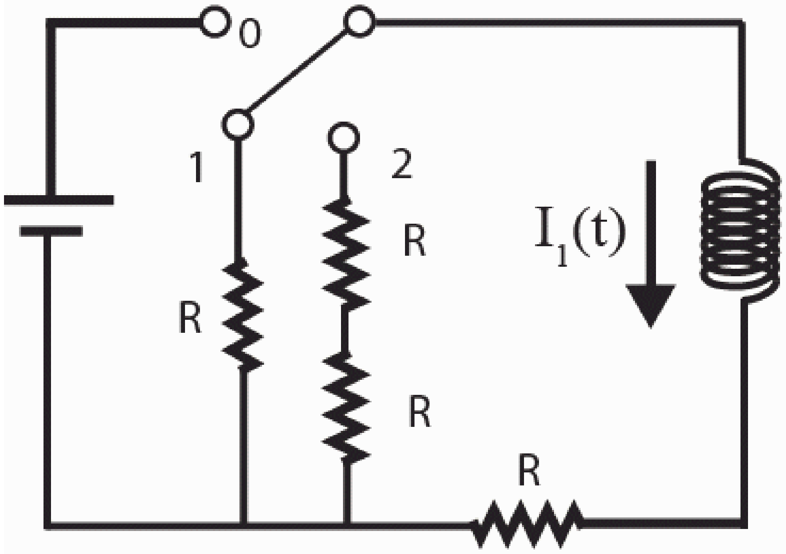
$$\tau_1 = \frac{L}{2R} \qquad \tau_2 = \frac{L}{3R}$$

Compare RL Circuits: Question 1 (N = 717)



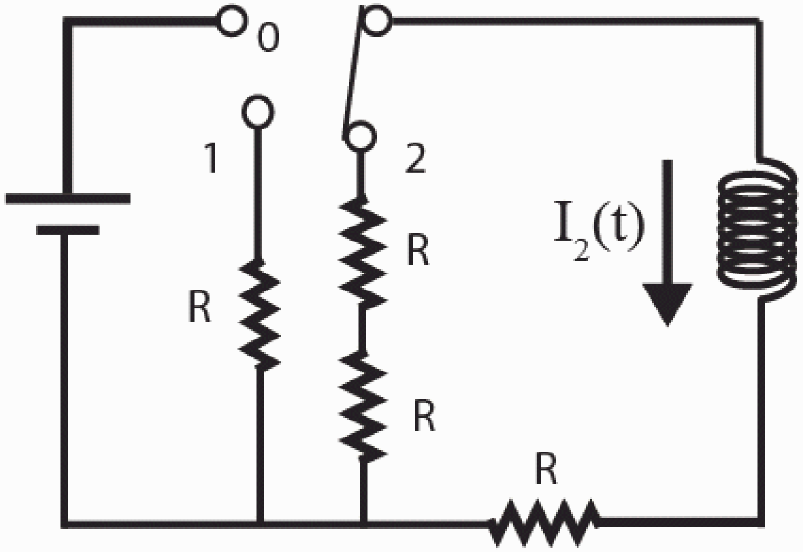
CheckPoint 3b

After long time at 0, moved to 1



Case 1

After long time at 0, moved to 2



Case 2

Immediately after switch moved, in which case is the voltage across the inductor larger?

- A) Case 1
- [✓ B) Case 2]
- C) The same

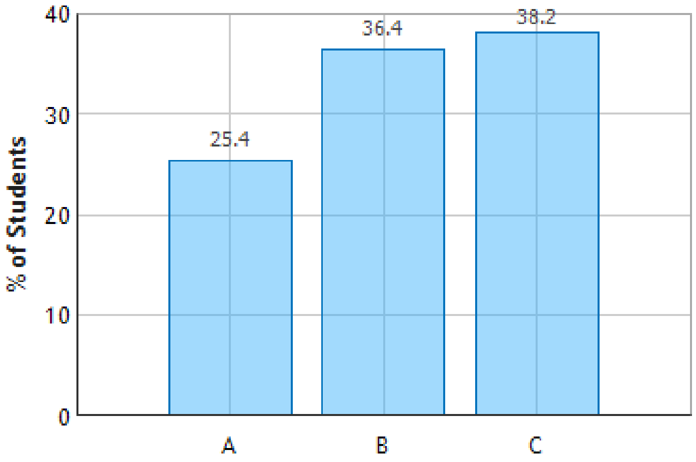
After switch moved:

$$V_{L1} = \frac{V}{R}2R$$

Before switch moved: $I = \frac{V}{R}$

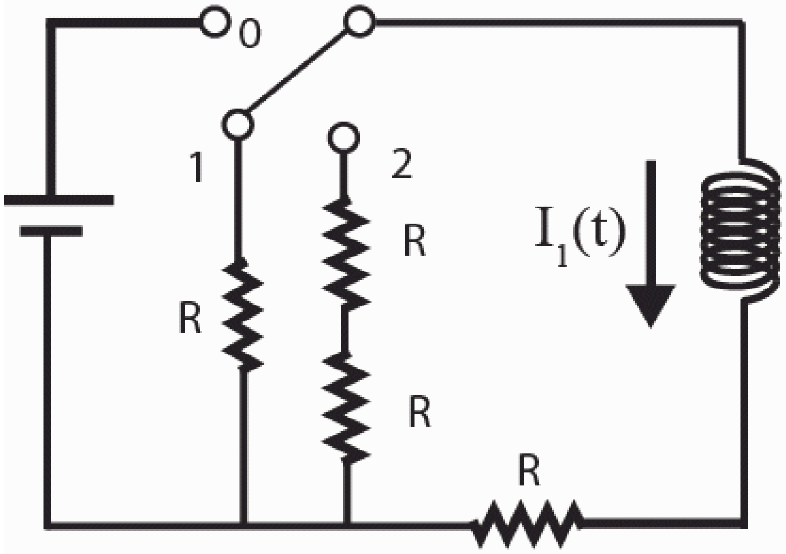
$$V_{L2} = \frac{V}{R}3R$$

Compare RL Circuits: Question 3 (N = 717)



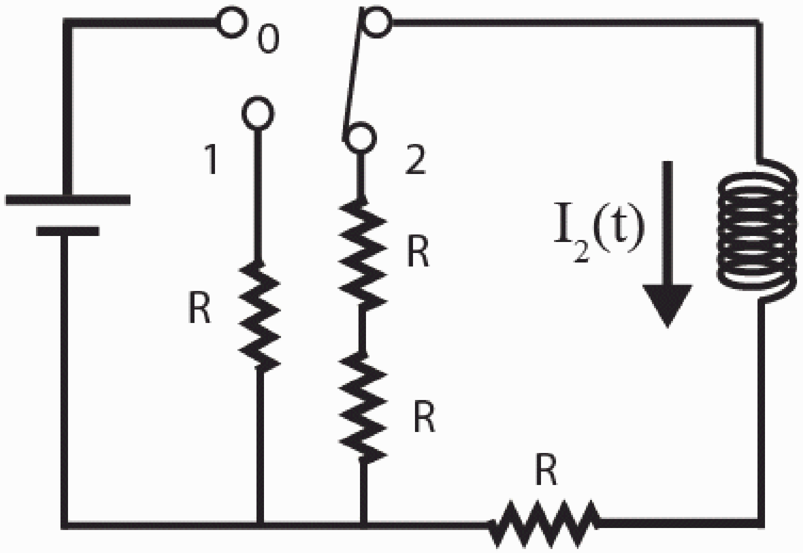
CheckPoint 3c

After long time at 0, moved to 1



Case 1

After long time at 0, moved to 2



Case 2

After switch moved for finite time, in which case is the current through the inductor larger?

[✓ A) Case 1]
B) Case 2
C) The same

After awhile

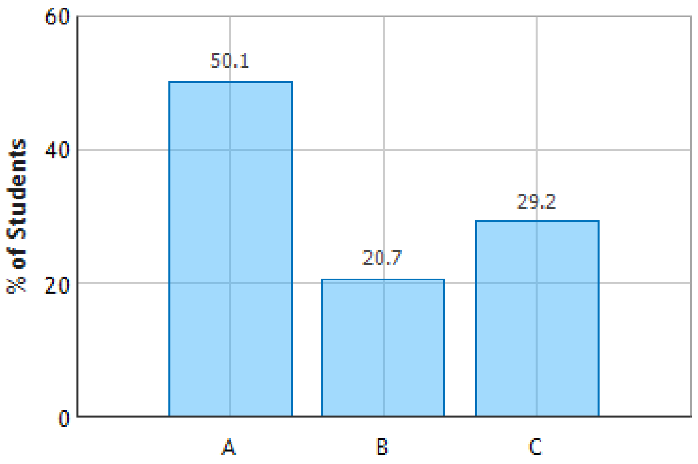
$$I_1 = Ie^{-t/\tau_1}$$

$$I_2 = Ie^{-t/\tau_2}$$

$$\tau_1 > \tau_2$$

Immediately after: $I_1 = I_2$

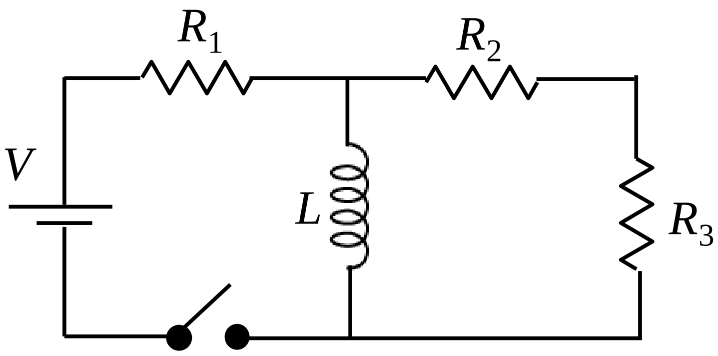
Compare RL Circuits: Question 5 (N = 716)



Calculation

The switch in the circuit shown has been open for a long time. At $t = 0$, the switch is closed.

What is dI_L/dt, the time rate of change of the current through the inductor immediately after switch is closed



Conceptual Analysis

Once switch is closed, currents will flow through this 2-loop circuit.

KVR and KCR can be used to determine currents as a function of time.

Strategic Analysis

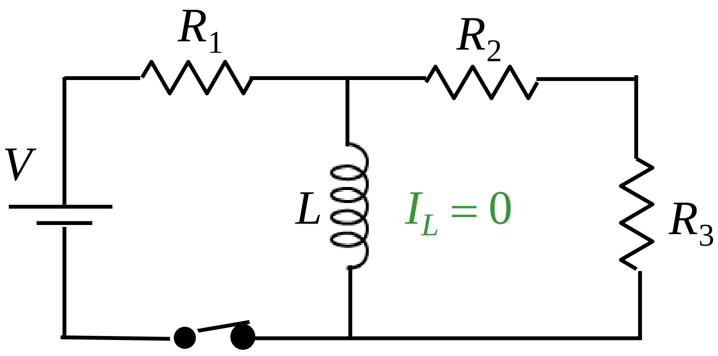
Determine currents immediately after switch is closed.

Determine voltage across inductor immediately after switch is closed.

Determine dI_L/dt immediately after switch is closed.

Calculation

The switch in the circuit shown has been open for a long time. At $t = 0$, the switch is closed.



What is I_L, the current in the inductor, immediately after the switch is closed?

A) $I_L = V/R_1$ up

B) $I_L = V/R_1$ down

C) $I_L = 0$

INDUCTORS: Current cannot change discontinuously !

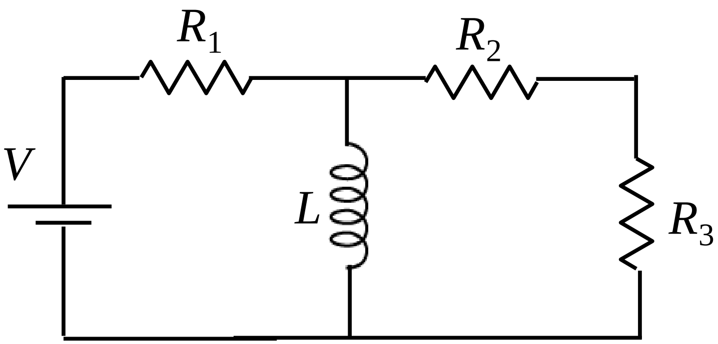
↓

Current through inductor immediately after switch is closed
is the same as
the current through inductor immediately before switch is closed

Immediately before switch is closed: $I_L = 0$ since no battery in loop

Calculation

The switch in the circuit shown has been open for a long time. At $t = 0$, the switch is closed.



$$I_L(t = 0+) = 0$$

What is the magnitude of I_2, the current in R_2, immediately after the switch is closed?

A) $I_2 = \dfrac{V}{R_1}$

B) $I_2 = \dfrac{V}{R_2 + R_3}$

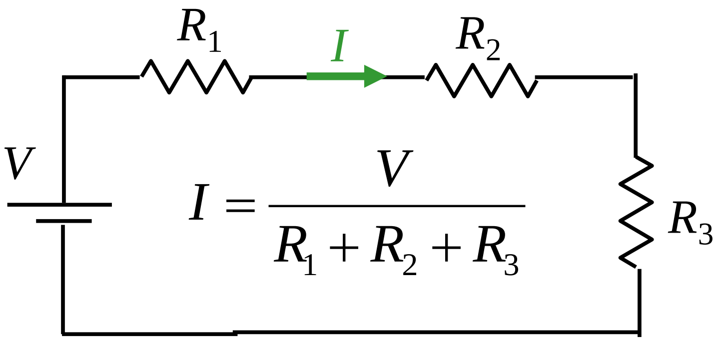
$\boxed{\text{C) } I_2 = \dfrac{V}{R_1 + R_2 + R_3}}$

D) $I_2 = \dfrac{VR_2R_3}{R_2 + R_3}$

We know $I_L = 0$ immediately after switch is closed

↓

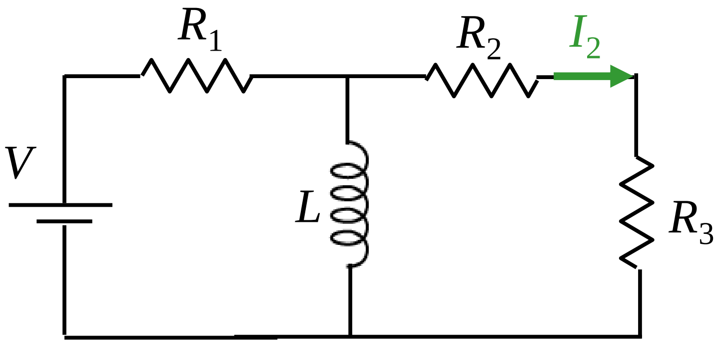
Immediately after switch is closed, circuit looks like:



$$I = \frac{V}{R_1 + R_2 + R_3}$$

Calculation

The switch in the circuit shown has been open for a long time. At $t = 0$, the switch is closed.



$I_L(t = 0 +) = 0$ $I_2(t = 0 +) = V/(R_1 + R_2 + R_3)$

What is the magnitude of V_L, the voltage across the inductor, immediately after the switch is closed?

A) $V_L = V\dfrac{R_2R_3}{R_1}$ B) $V_L = V$ C) $V_L = 0$ D) $V_L = V\dfrac{R_2R_3}{R_1(R_2+R_3)}$ $\boxed{\text{E) } V_L = V\dfrac{R_2+R_3}{R_1+R_2+R_3}}$

Kirchhoff's Voltage Law,

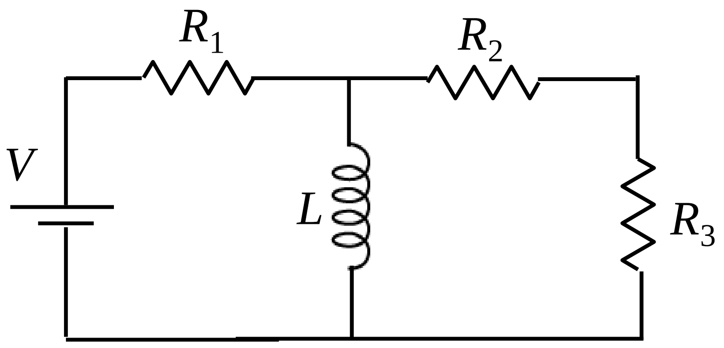
$V_L - I_2 R_2 - I_2 R_3 = 0$ $V_L = I_2 (R_2 + R_3)$

$$V_L = \frac{V}{R_1 + R_2 + R_3}(R_2 + R_3)$$

Calculation

The switch in the circuit shown has been open for a long time. At $t = 0$, the switch is closed.

What is dI_L/dt, the time rate of change of the current through the inductor immediately after switch is closed



$V_L(t = 0 +) = V(R_2+ R_3)/(R_1+ R_2+ R_3)$

A) $\frac{dI_L}{dt} = \frac{V}{L}\frac{R_2 + R_3}{R_1}$ B) $\frac{dI_L}{dt} = 0$ $\boxed{\text{C) } \frac{dI_L}{dt} = \frac{V}{L}\frac{R_2 + R_3}{R_1 + R_2 + R_3}}$ D) $\frac{dI_L}{dt} = \frac{V}{L}$

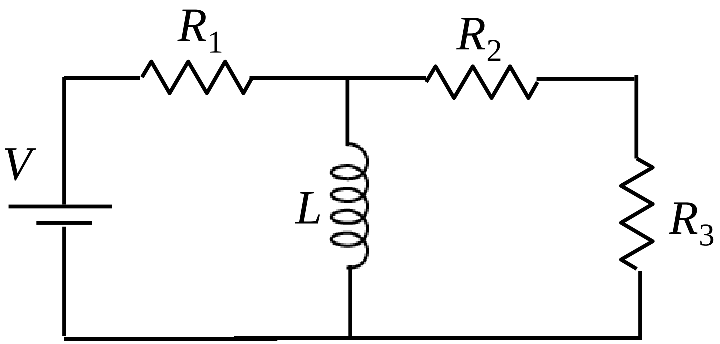
The time rate of change of current through the inductor $(dI_L /dt) = V_L /L$

➡ $$\frac{dI_L}{dt} = \frac{V}{L}\frac{R_2 + R_3}{R_1 + R_2 + R_3}$$

Follow Up

The switch in the circuit shown has been closed for a long time.

What is I_2, the current through R_2 ?
(Positive values indicate current flows to the right)



A) $I_2 = +\dfrac{V}{R_2 + R_3}$

B) $I_2 = +\dfrac{V(R_2R_3)}{R_1 + R_2 + R_3}$

C) $\boxed{I_2 = 0}$

D) $I_2 = -\dfrac{V}{R_2 + R_3}$

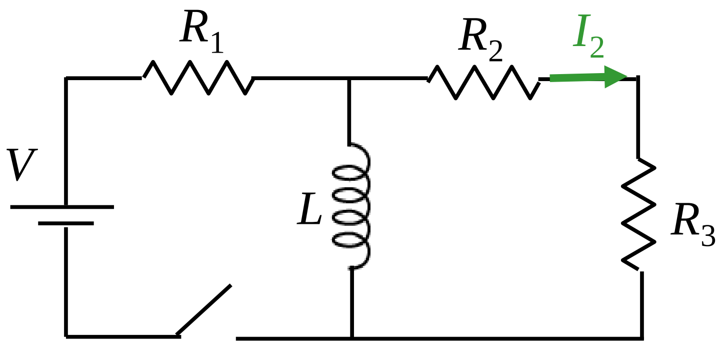
After a long time, $dI/dt = 0$
Therefore, the voltage across $L = 0$
Therefore the voltage across $R_2 + R_3 = 0$
Therefore the current through $R_2 + R_3$ must be zero!

Follow Up 2

The switch in the circuit shown has been closed for a long time at which point, the switch is opened.

What is I_2, the current through R_2 immediately after switch is opened ?

(Positive values indicate current flows to the right)



A) $I_2 = +\frac{V}{R_1 + R_2 + R_3}$

B) $I_2 = +\frac{V}{R_1}$

C) $I_2 = 0$

D) $\boxed{I_2 = -\frac{V}{R_1}}$

E) $I_2 = -\frac{V}{R_1 + R_2 + R_3}$

Current through inductor immediately after switch is opened
is the same as
the current through inductor immediately before switch is opened

Immediately before switch is opened: $I_L = V/R_1$

Immediately after switch is opened: I_L flows in right loop
Therefore, $I_L = -V/R_1$