Your Comments

RC circuits were very hard for me, so I am scared of RL Circuits.

I thought this one was pretty tough, plus I am exhausted from my Diff Eq test...

This was difficult. I just need good conceptual understanding of inductors and then this topic will become much easier.

Why did the inductor date the resistor? He wanted a time-constant relationship.

Will RL circuits be on the test? Because I'm very confused by them. Yes.

It's very annoying to have the Smart Physics spell check flag inductor as a misspelled word.

Pretty proud of the fact that I have INDUCTed this prelecture into my physics 212 CAPACITANCE in my brain.

Yesterday was what my high school chem teacher called "Avagadro Day" because of the 10^23 in Avagadro's number. She nerded out and made guacaMOLE and partied. We should too. Partying can still be described by physics, so I find it reasonable.

Some Exam Stuff

Exam 2: Wed. Oct. 29 at 7:00

- Covers material in Lectures 9 – 18
- Sign up in Gradebook for Conflict Exam at 5:15pm
- Link in Gradebook if you have a double-conflict

Exam Preparation:

- Study HW, Discussion, Checkpoints
- Old Exams are a good way to assess what you need to know
- Prelecture of Fall 2010 solutions available (10/29 "prelecture")
- Video Solutions of Spring 2014 Hour Exam 2 (10/29 "optional HW")

Extra Office Hours:

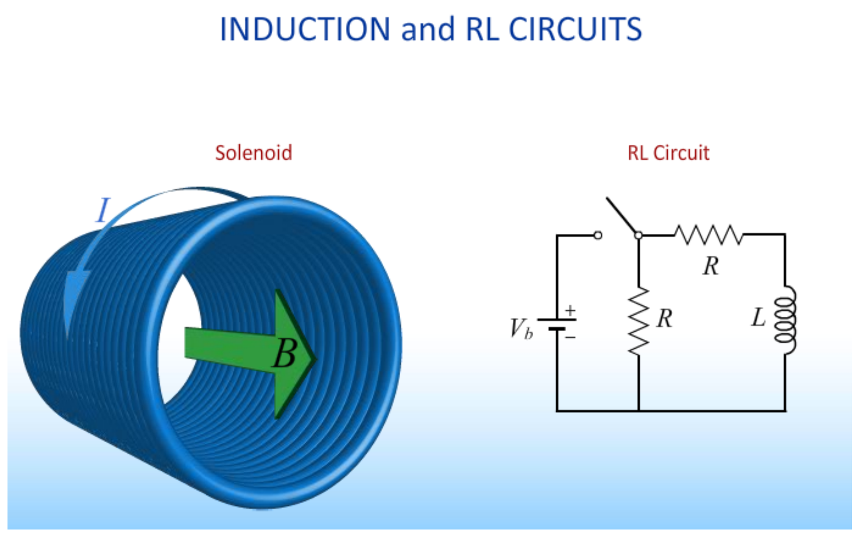
- Fri., Sun., Mon., Tue., Wed. (see website for schedule and rooms)

Physics 212
Lecture 18

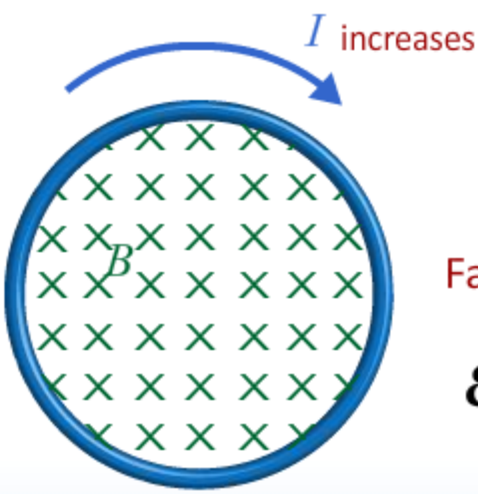
Today's Concepts:

A) Induction

B) RL Circuits



From the Prelecture: Self Inductance



Self-Inductance

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

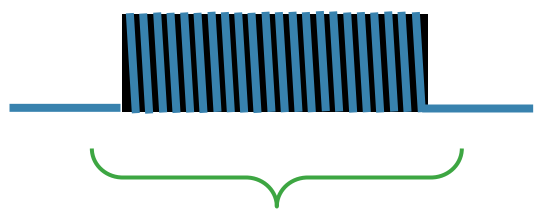
SI Unit

H = T-m²/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"…



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

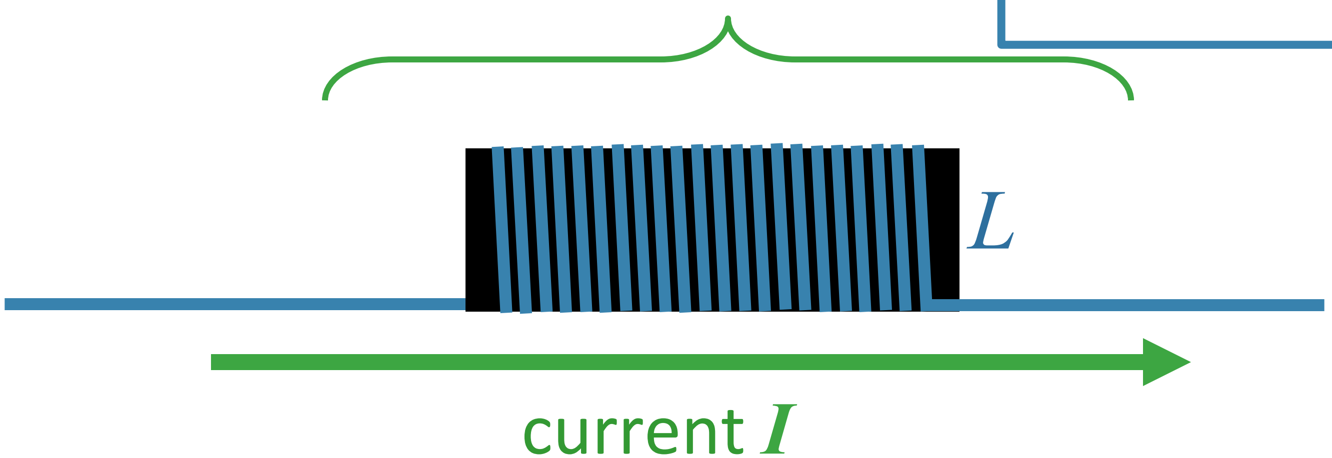
What this really means:

emf induced across L tries to keep I constant.

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

Short Term $I_{before} = I_{after}$

Long Term $V_L = 0$



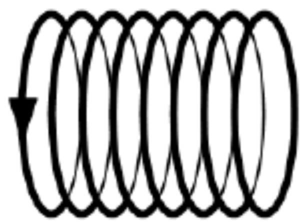
Inductors prevent discontinuous current changes!

It's like inertia!

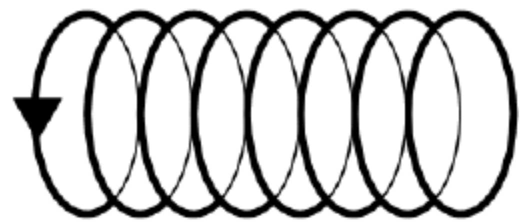
CheckPoint 2

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

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



A

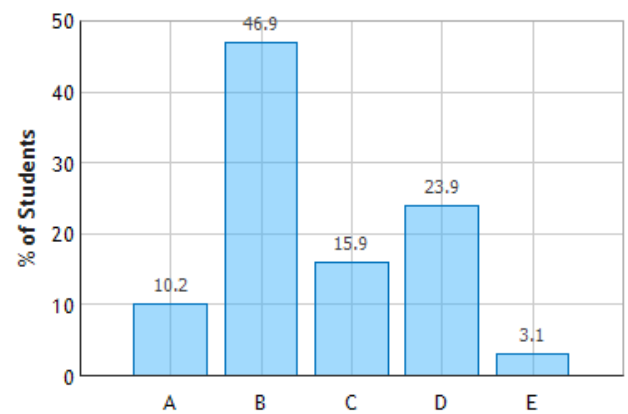


B

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

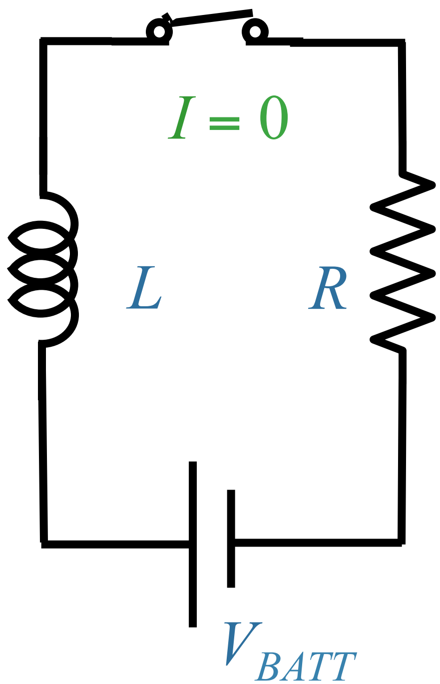
Compare the inductance of the two solenoids

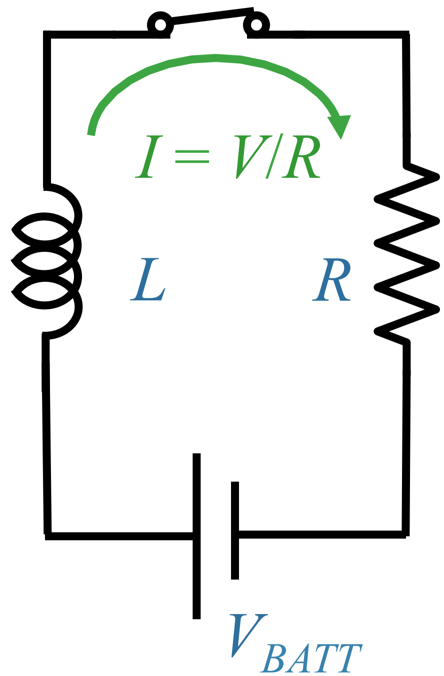
A) $L_A = 4\,L_B$
B) $\boxed{L_A = 2\,L_B}$
C) $L_A = L_B$
D) $L_A = (1/2)\,L_B$
E) $L_A = (1/4)\,L_B$

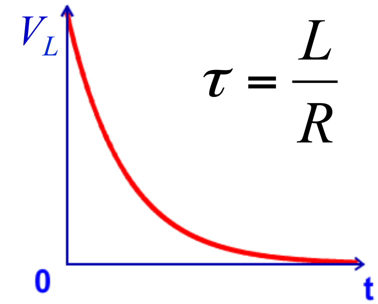


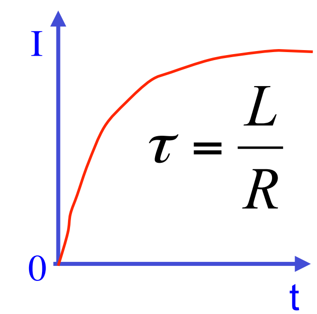
How to think about RL circuits Episode 1:

When no current is flowing initially:









At $t = 0$: I_L unchanged

$I_L = 0$
$V_R = 0$
$V_L = V_{BATT}$
(L is like an open circuit)

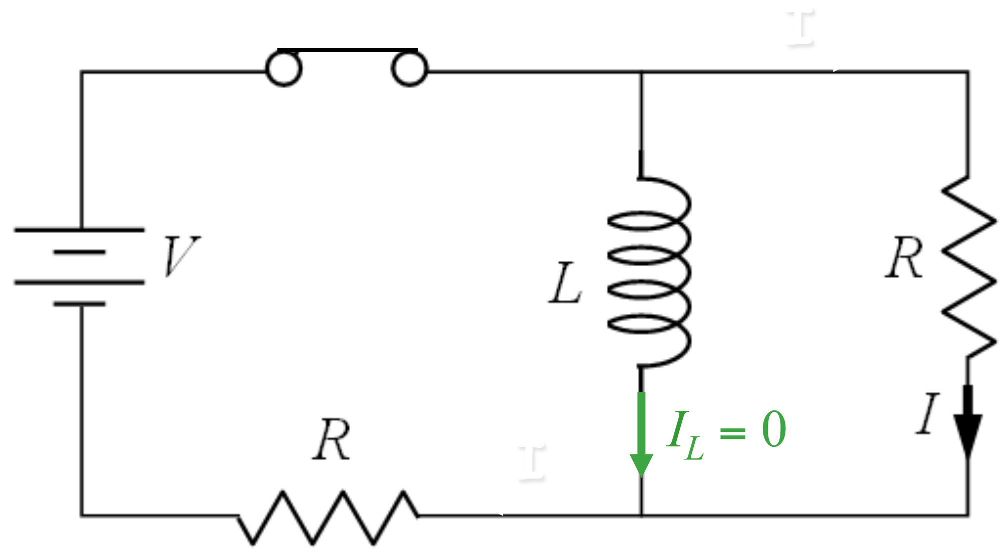
At $t >> L/R$: $V_L = 0$

$V_L = 0$
$V_R = V_{BATT}$
$I = V_{BATT}/R$
(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) $\boxed{I = V/2R}$

C) $I = 0$

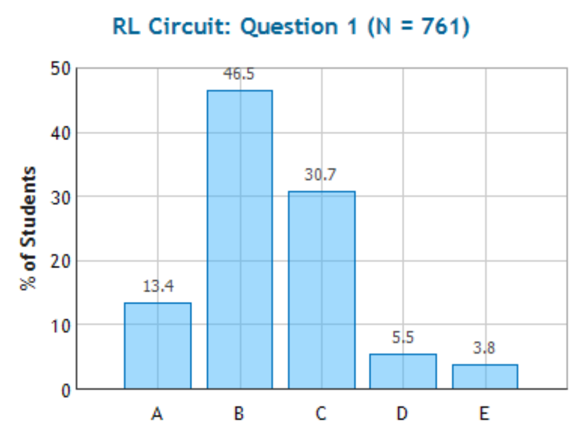
D) $I = -V/2R$

E) $I = -V/R$

Before: $I_L = 0$

After: $I_L = 0$

$\longrightarrow$ $I = +\, V/2R$

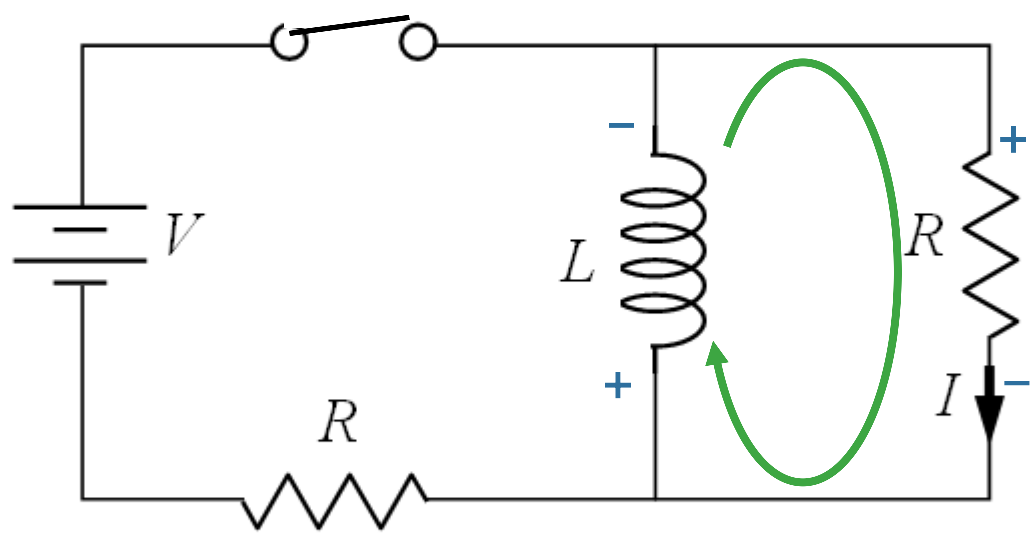


RL Circuit (Long Time)

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) $\boxed{I = 0}$
D) $I = -V/2R$
E) $I = -V/R$

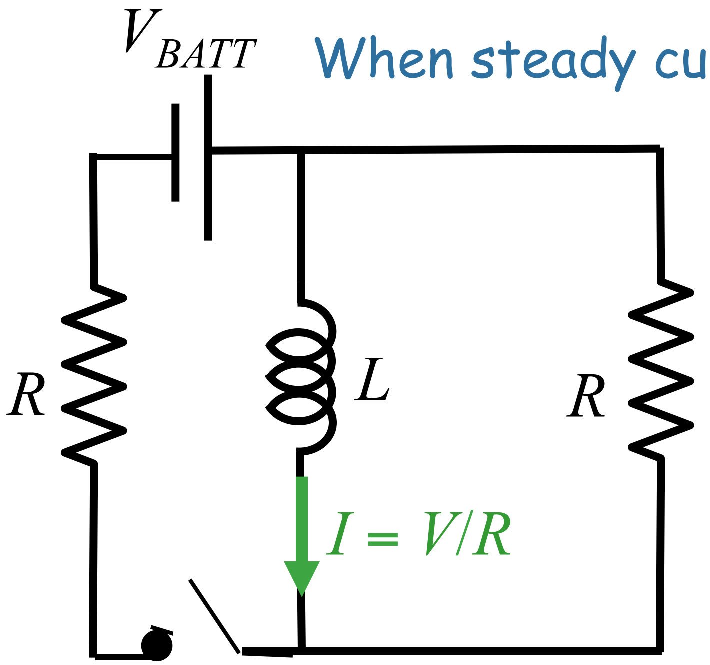


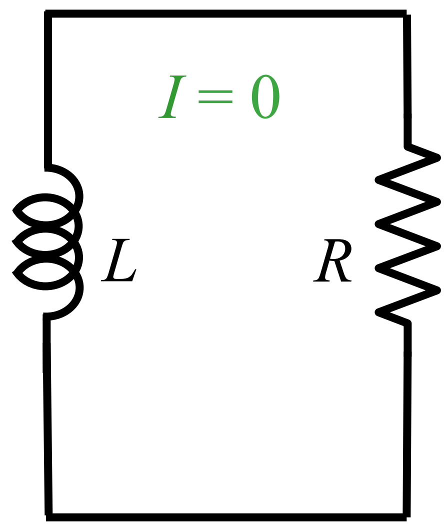
After a long time in any static circuit: $V_L = 0$

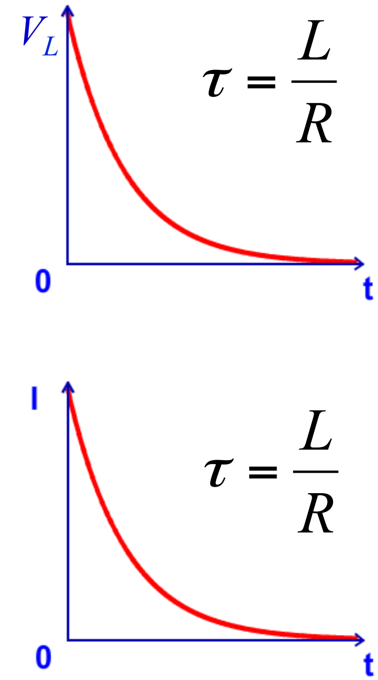
KVR:
$V_L + IR = 0$

How to Think about RL Circuits Episode 2:

When steady current is flowing initially: then switch is opened







At $t = 0$: I_L unchanged

$I = V_{BATT}/R$

$V_R = IR$

$V_L = V_R$

At $t >> L/R$: $V_L = 0$

$V_L = 0$

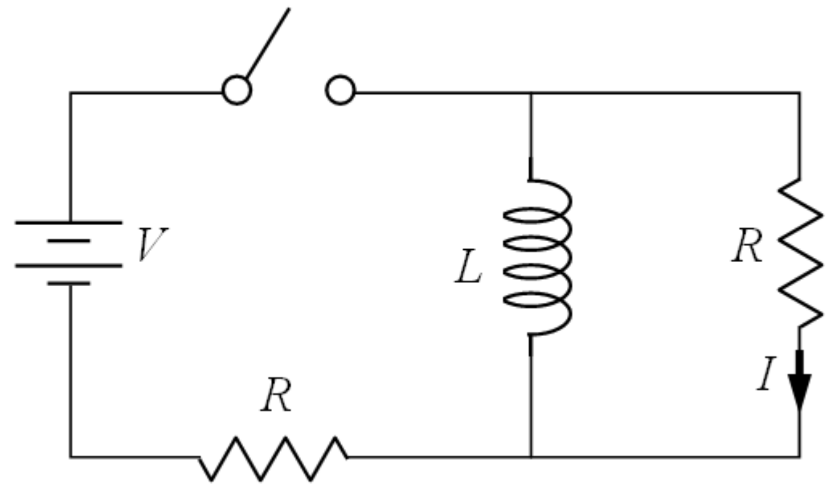
$V_R = 0$

$I = 0$

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?

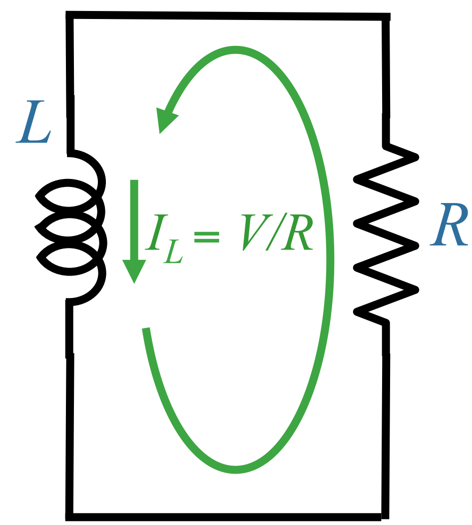


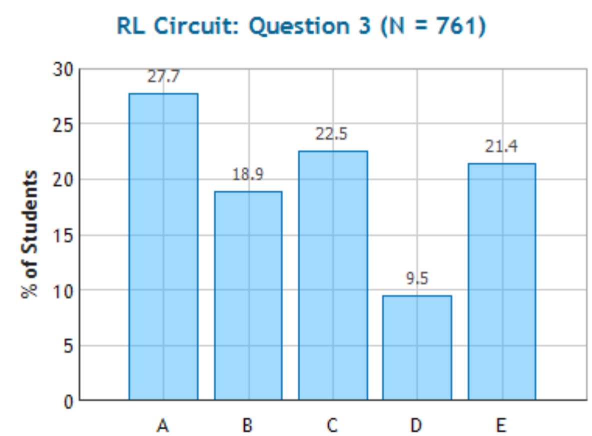
(+ is in the direction of the arrow)

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

Current through inductor cannot change DISCONTINUOUSLY

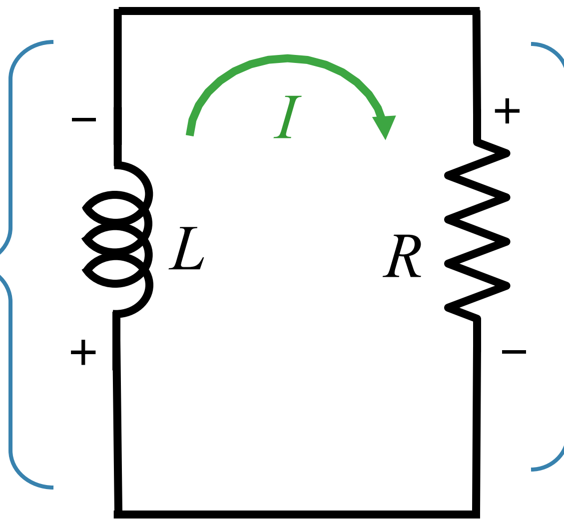
circuit when switch opened



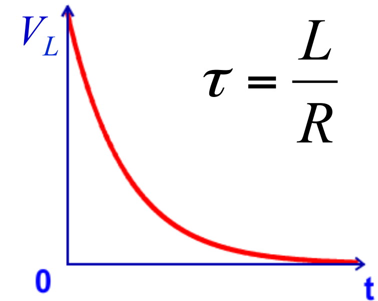


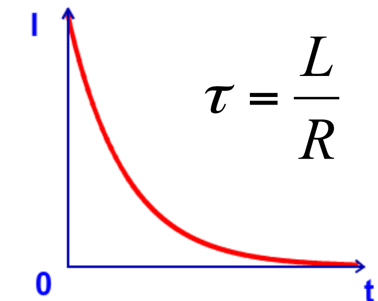
Why is there Exponential Behavior?

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



$$V = IR$$

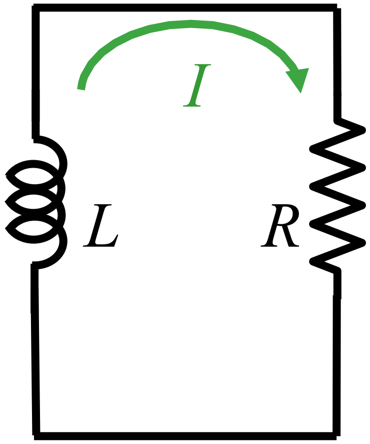


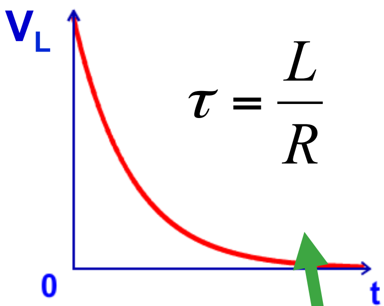


$$L\frac{dI}{dt} + IR = 0$$

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

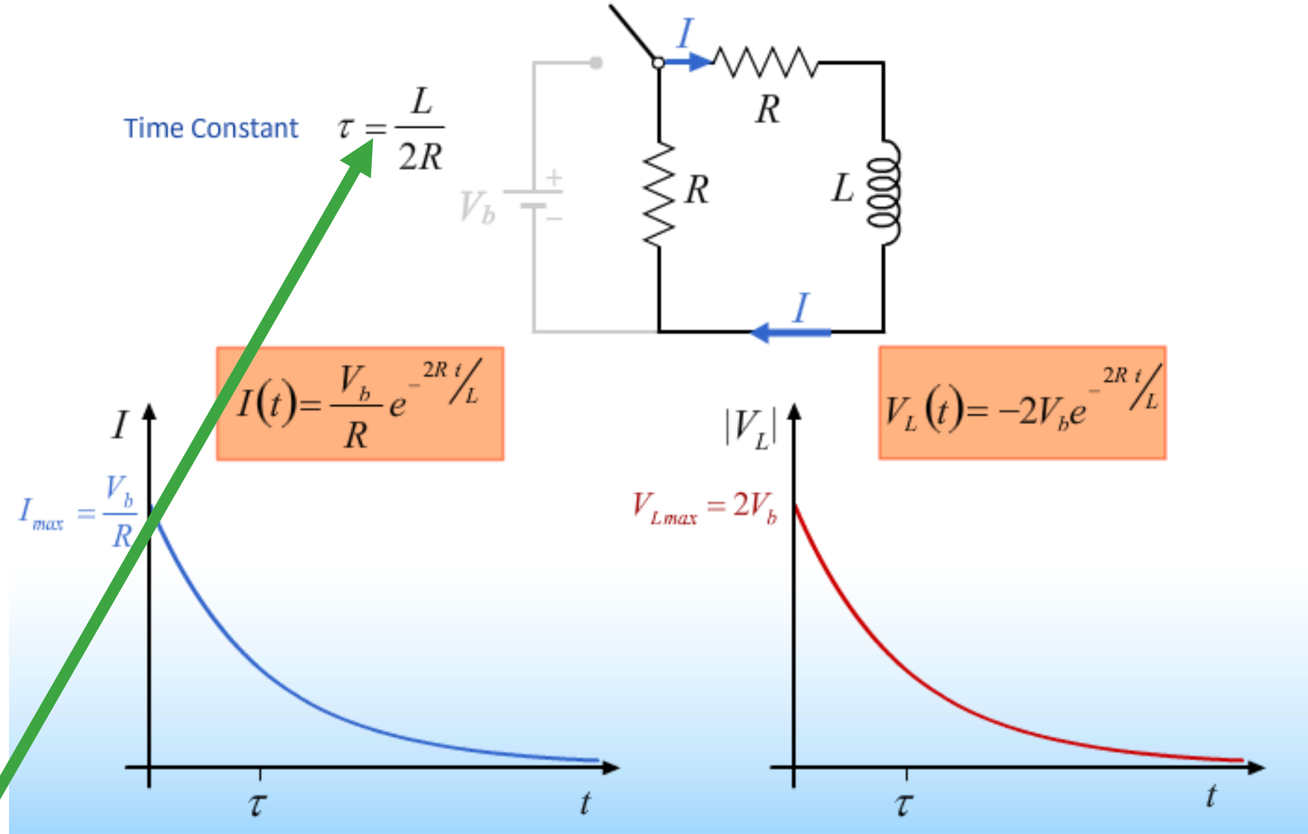
where $\tau = \frac{L}{R}$





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

Lecture:

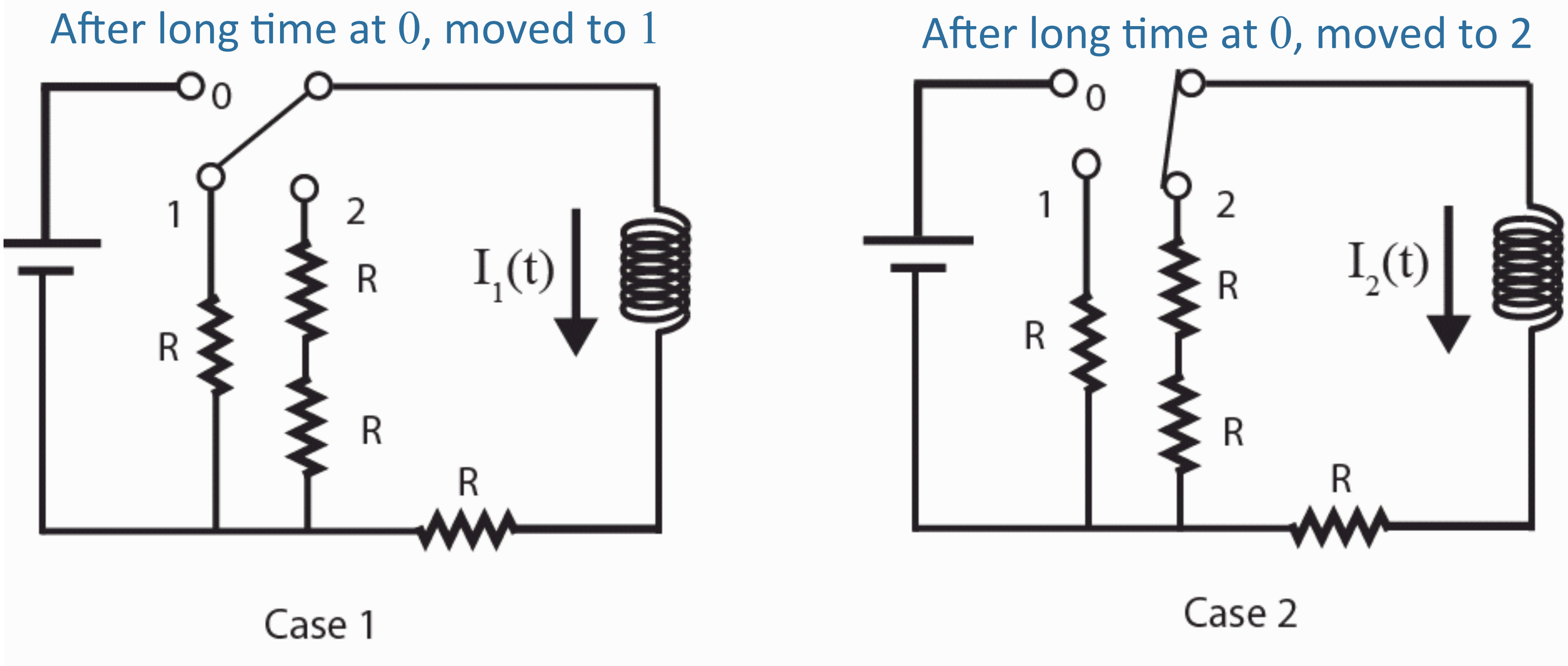


Prelecture:

Did we mess up?

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

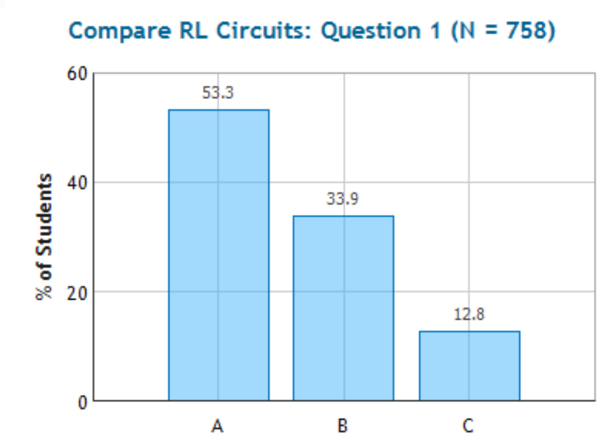
CheckPoint 3a



After switch moved, which case has larger time constant?

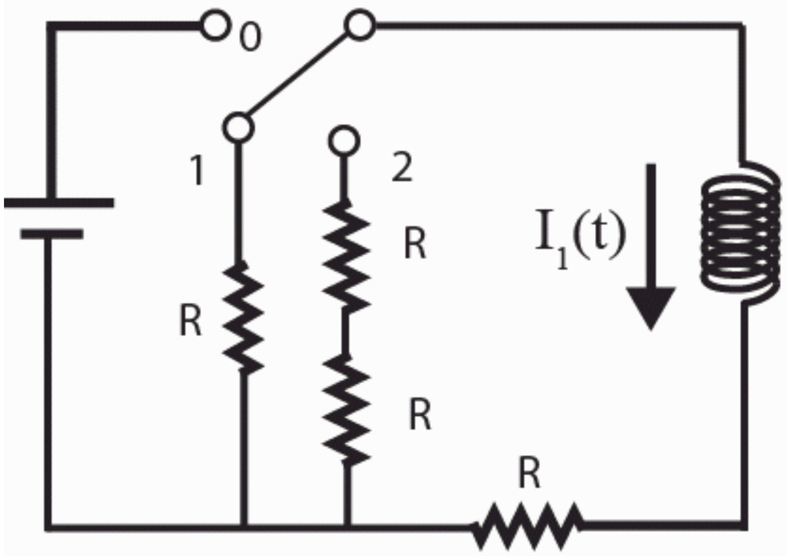
- A) Case 1
- B) Case 2
- C) The same

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



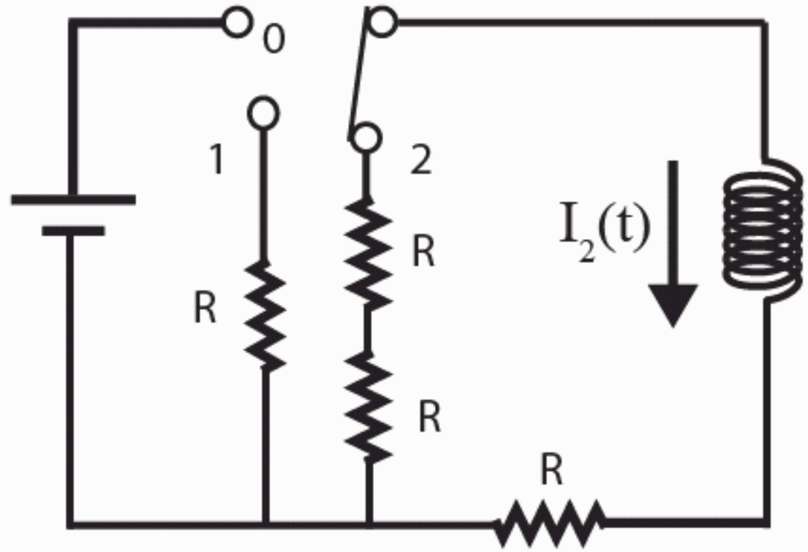
CheckPoint 3b

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?

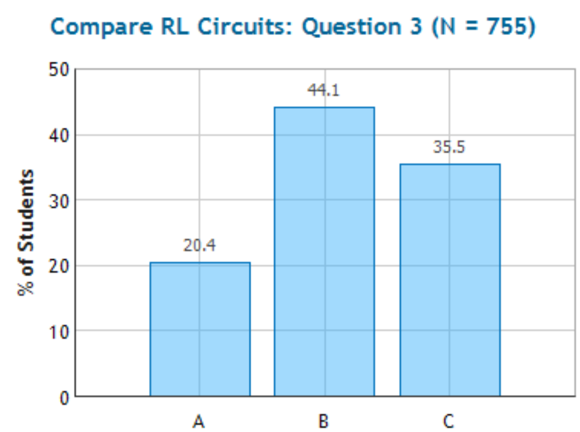
A) Case 1
B) Case 2
C) The same

After switch moved:

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

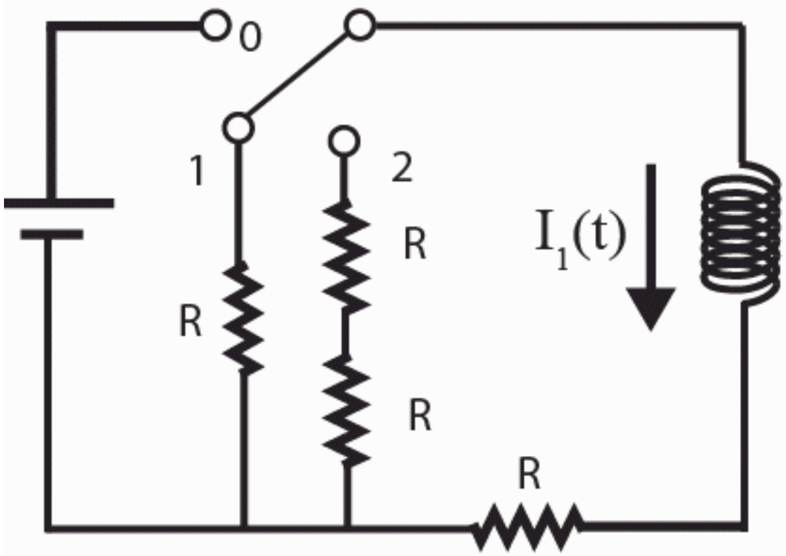
$$V_{L2} = \frac{V}{R}3R$$

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



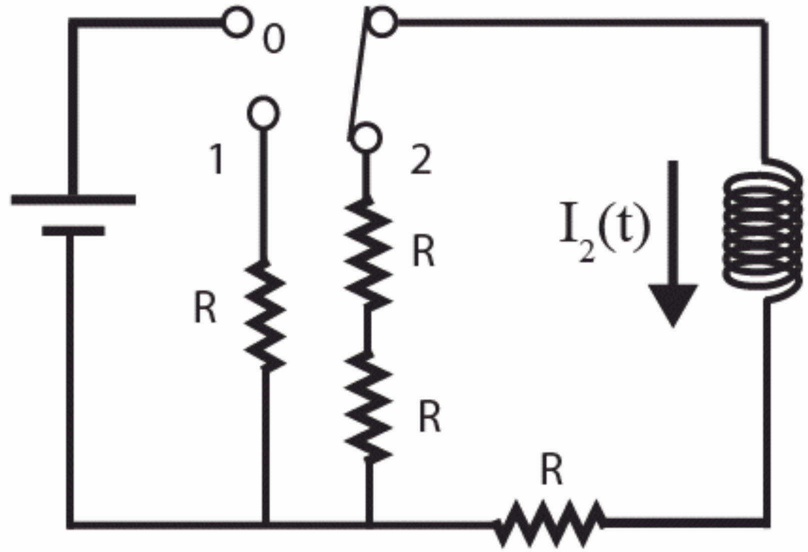
CheckPoint 3c

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

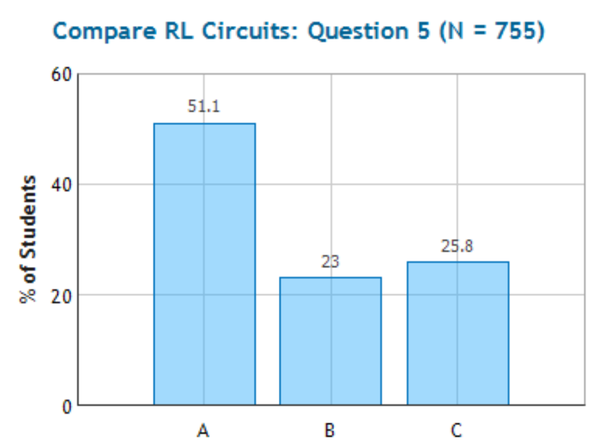
Immediately after: $I_1 = I_2$

After awhile

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

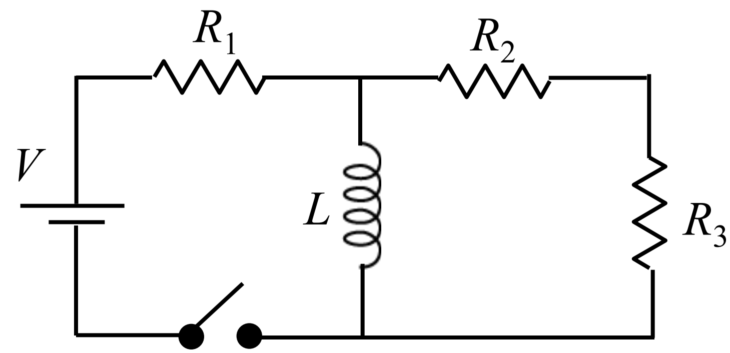
$$I_2 = Ie^{-t/\tau_2}$$

$$\tau_1 > \tau_2$$



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

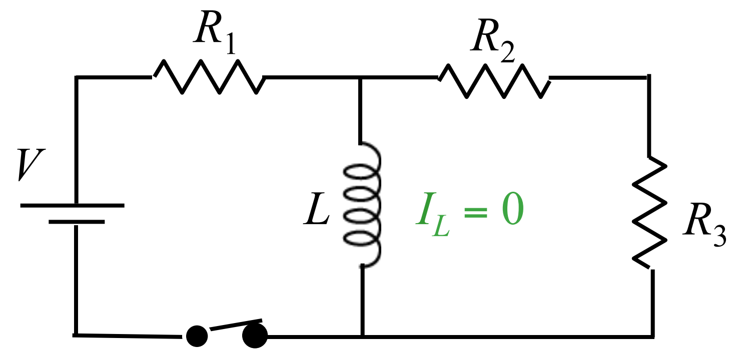
Determine currents immediately after switch is closed.

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) $\boxed{I_L = 0}$

INDUCTORS: Current cannot change discontinuously !

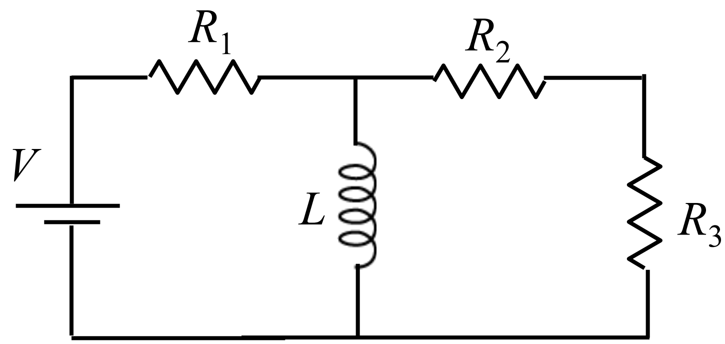
↓

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.



$I_L(t = 0+) = 0$

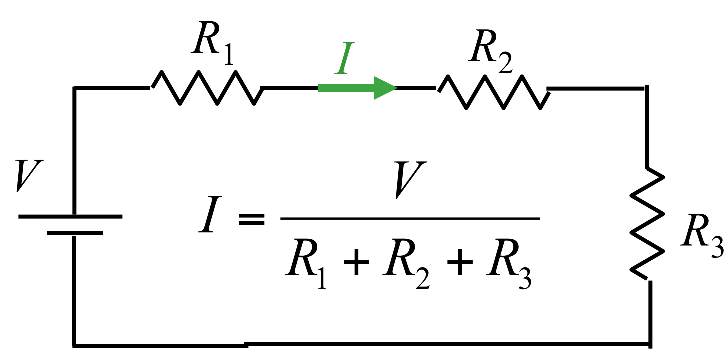
What is the magnitude of I_2, the current in R_2, immediately after the switch is closed?

A) $I_2 = \dfrac{V}{R_1}$ B) $I_2 = \dfrac{V}{R_2 + R_3}$ C) $\boxed{I_2 = \dfrac{V}{R_1 + R_2 + R_3}}$ D) $I_2 = \dfrac{VR_2R_3}{R_2 + R_3}$

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

↓

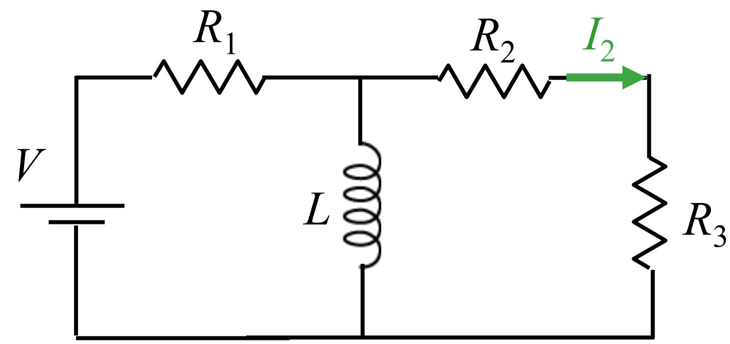
Immediately after switch is closed, circuit looks like:



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

Calculation

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



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

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

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

Kirchhoff's Voltage Law,

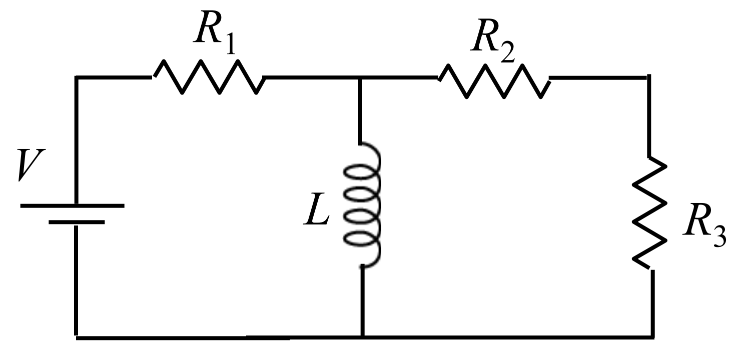
$V_L - I_2 R_2 - I_2 R_3 = 0 \qquad V_L = I_2 (R_2 + R_3)$

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

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) $\dfrac{dI_L}{dt} = \dfrac{V}{L}\dfrac{R_2 + R_3}{R_1}$

B) $\dfrac{dI_L}{dt} = 0$

C) $\dfrac{dI_L}{dt} = \dfrac{V}{L}\dfrac{R_2 + R_3}{R_1 + R_2 + R_3}$

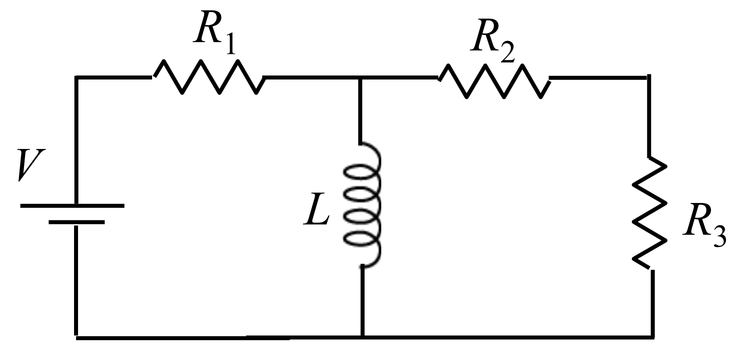
D) $\dfrac{dI_L}{dt} = \dfrac{V}{L}$

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)

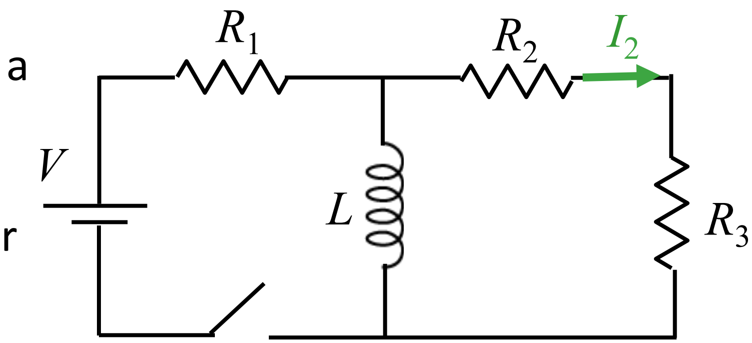
A) $I_2 = +\dfrac{V}{R_2 + R_3}$ B) $I_2 = +\dfrac{V(R_2 R_3)}{R_1 + R_2 + R_3}$ $\boxed{\text{C) } I_2 = 0}$ D) $I_2 = -\dfrac{V}{R_2 + R_3}$

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

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

C) $I_2 = 0$

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

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

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, $I_L = -V/R_1$