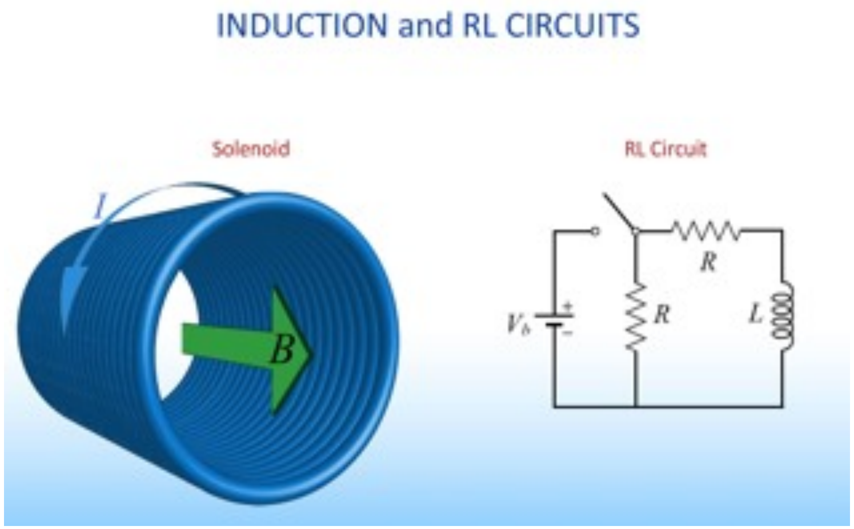
# *Electricity & Magnetism Lecture 18*

Today's Concepts:

A) Induction

B) RL Circuits



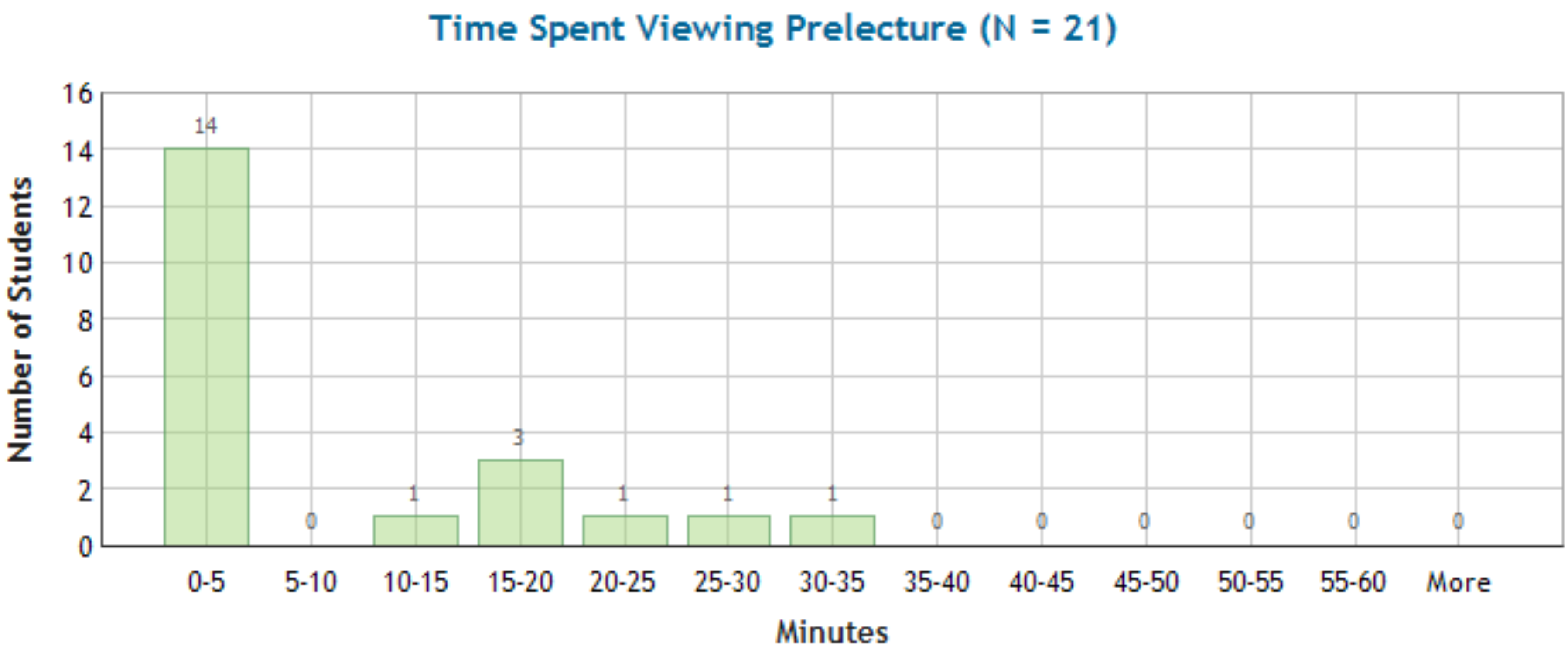
# Stuff you said..

Will there be more lab activities involving oscilloscopes? Unlike lab activities involving magnets, the oscilloscopes are foreign, new, and curiously interesting to play/learn with due to the above?

http://www.sfu.ca/phys/141/1134/Schedule141.pdf

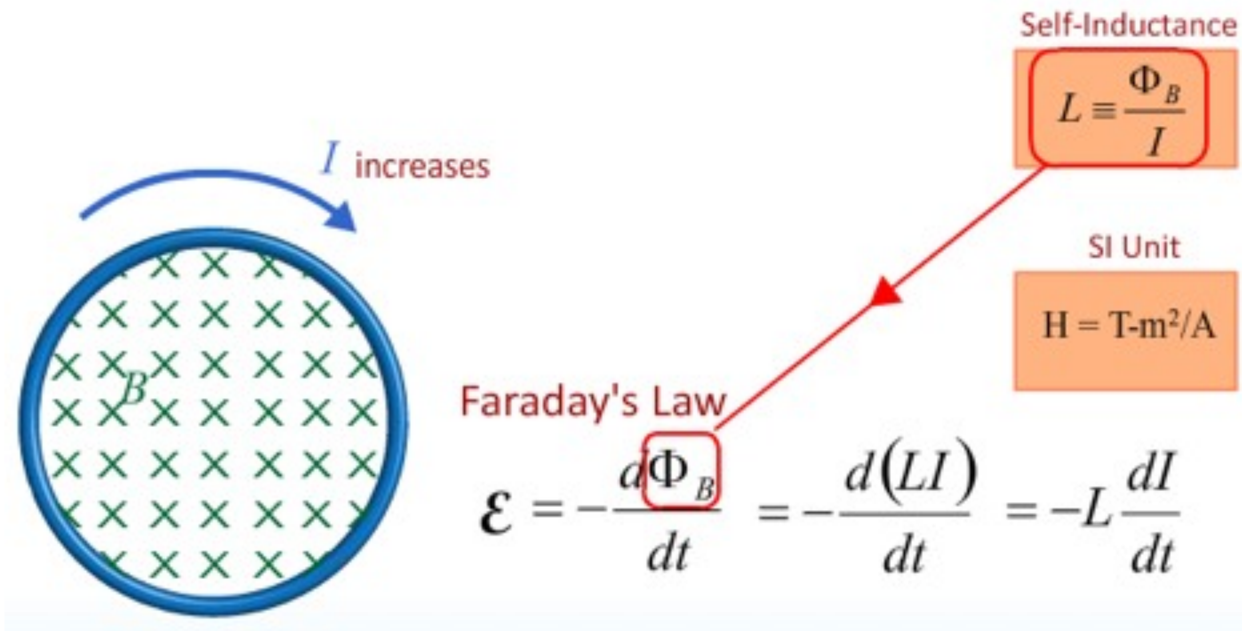
What are the exact differences between the Capacitor and Inductor. In which situation would I use the Capacitor instead of the Inductor or vice versa?

**Capacitors are yin — Inductors are yang**

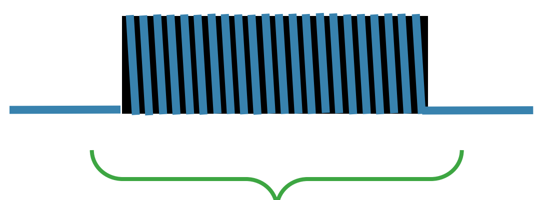


Time Spent Viewing Prelecture (N = 21)
Number of Students
16
14
12
10
8
6
4
2
0
14
0
1
3
1
1
1
0
0
0
0
0
0
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
More
Minutes

# From the Prelecture: Self Inductance




Wrap a wire into a coil to make an "inductor"…

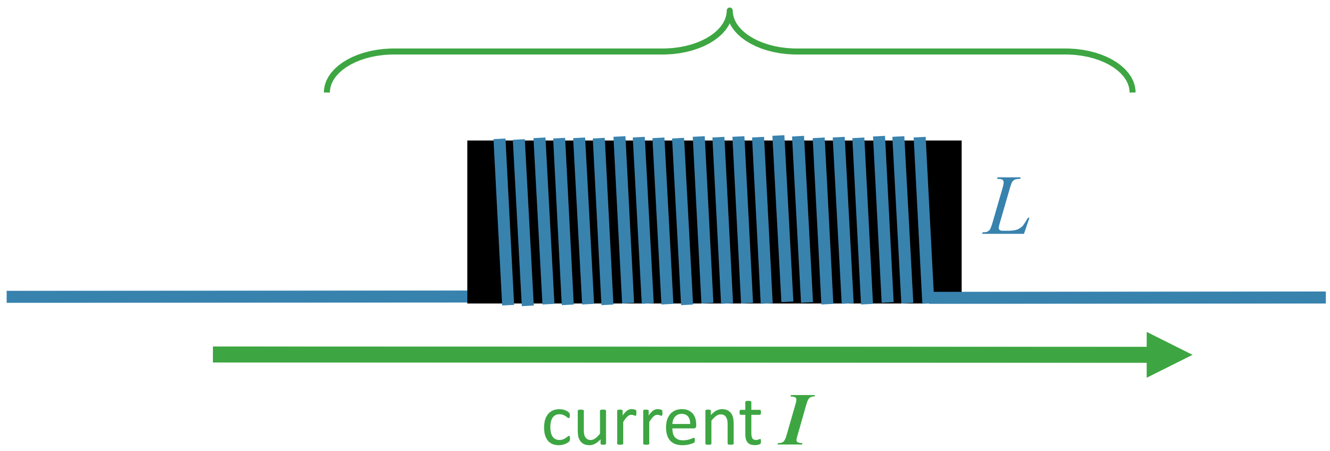


$$\varepsilon = -L\frac{dI}{dt}$$

# What this really means:

*emf* induced across $L$ tries to keep $I$ constant.

$$\varepsilon_L = -L\frac{dI}{dt}$$




Inductors prevent discontinuous current changes!

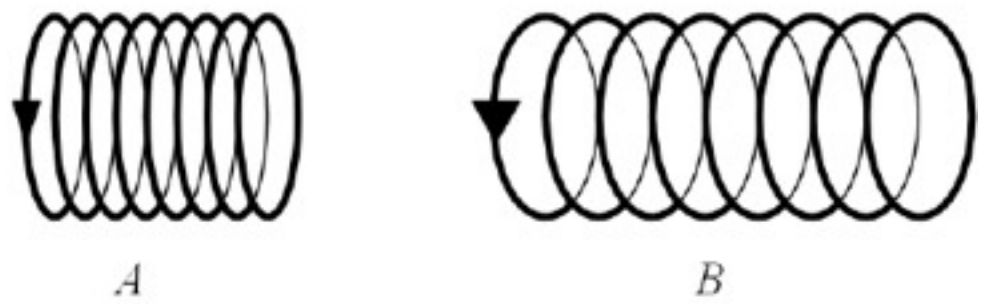
It's like inertia!

# 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 $A$

$$L_B = \mu_0 n^2 \pi r^2 z$$

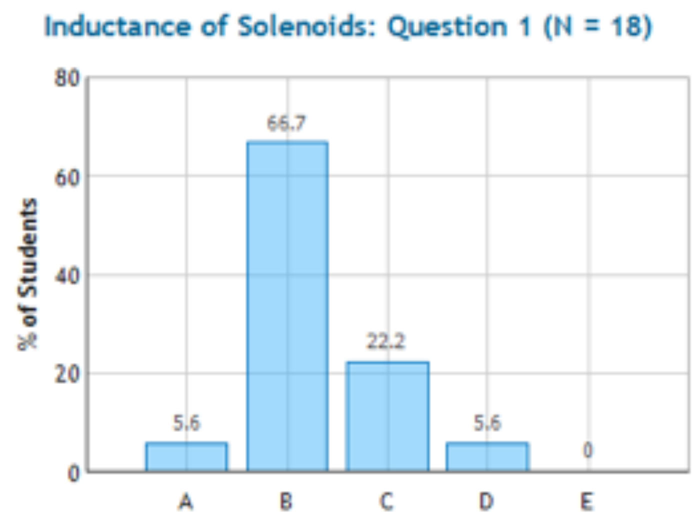
$(1/2)^2$    $2$




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

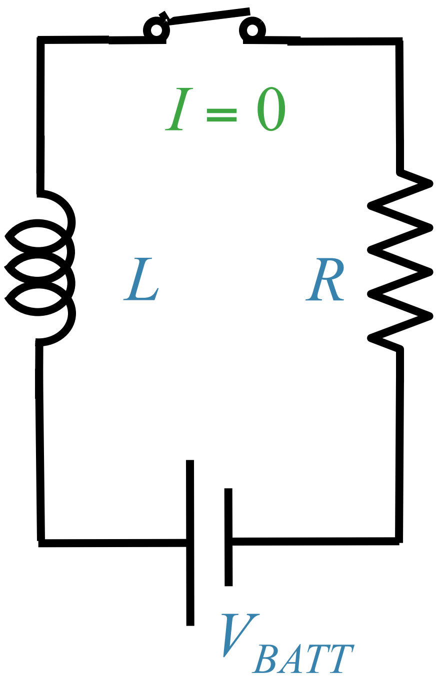
Compare the inductance of the two solenoids

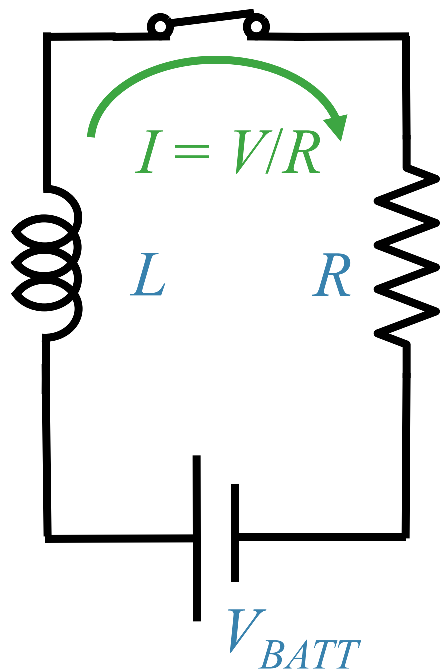
A) $L_A = 4\, L_B$
B) $L_A = 2\, L_B$
C) $L_A = L_B$
D) $L_A = (1/2)\, L_B$
E) $L_A = (1/4)\, L_B$

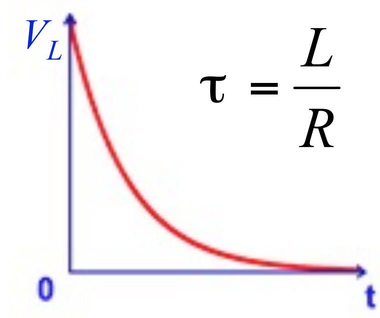


# How to think about RL circuits Episode 1:

## When no current is flowing initially:




### At $t = 0$:

$I = 0$

$V_L = V_{BATT}$

$V_R = 0$

($L$ is like a giant resistor)

### At $t >> L/R$:

$V_L = 0$

$V_R = V_{BATT}$

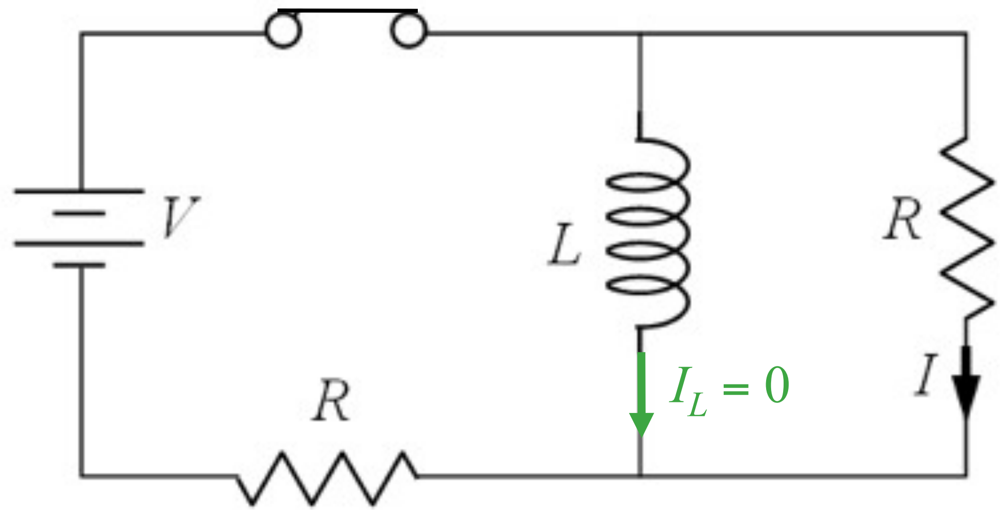
$I = V_{BATT}/R$

($L$ is like a short circuit)

# CheckPoint 4

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)

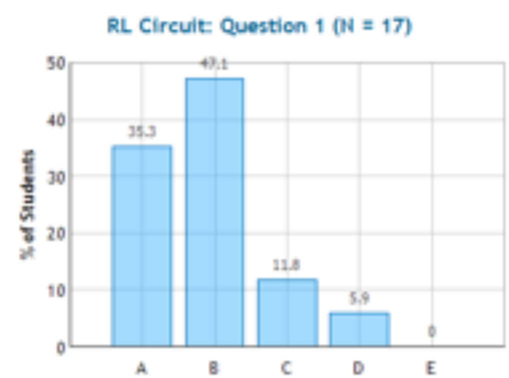
A) $I = V/R$

B) $I = V/2R$

C) $I = 0$

D) $I = -V/2R$

E) $I = -V/R$

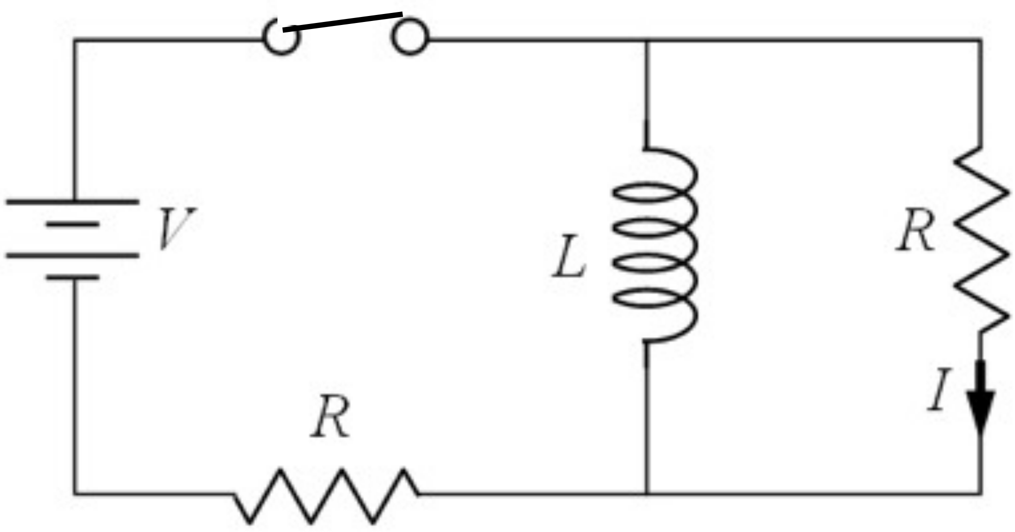


# RL Circuit (Long Time)

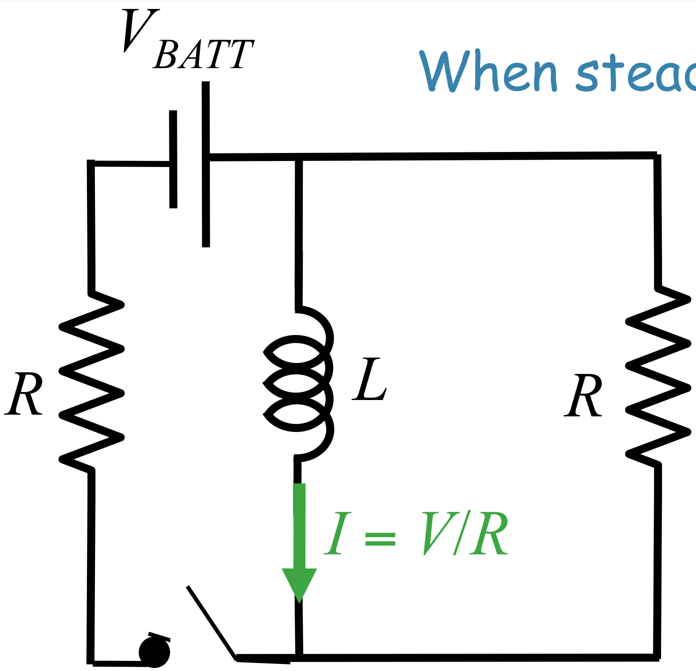
What is the current $I$ through the vertical resistor after the switch has been closed for a long time?

(+ is in the direction of the arrow)

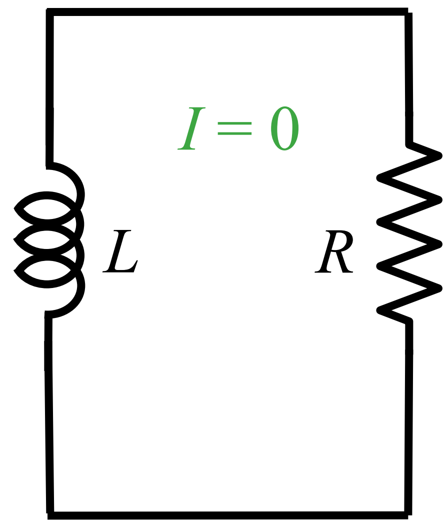
A) $I = V/R$
B) $I = V/2R$
C) $I = 0$
D) $I = -V/2R$
E) $I = -V/R$

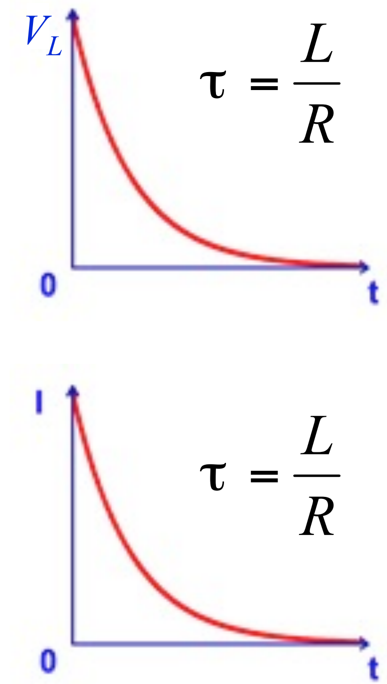


# How to Think about RL Circuits Episode 2:




When steady current is flowing initially:




## At $t = 0$:

$I = V_{BATT}/R$

$V_R = IR$

$V_L = V_R$

## At $t >> L/R$:

$I = 0$

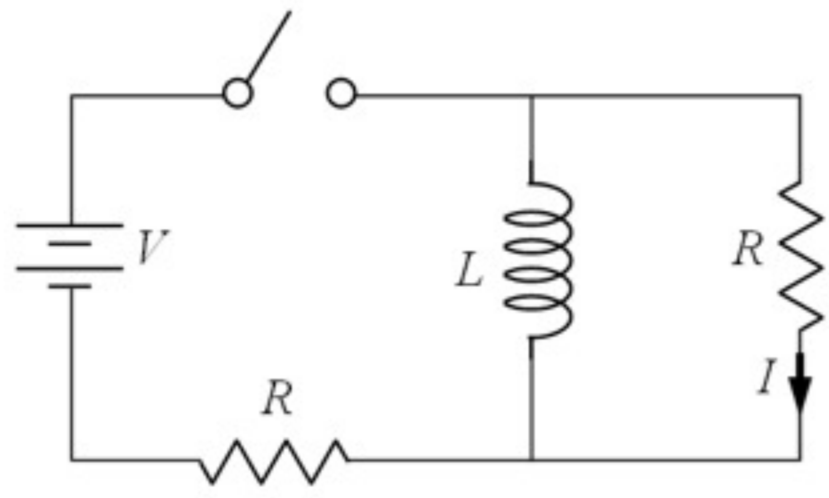
$V_L = 0$

$V_R = 0$

# CheckPoint 6

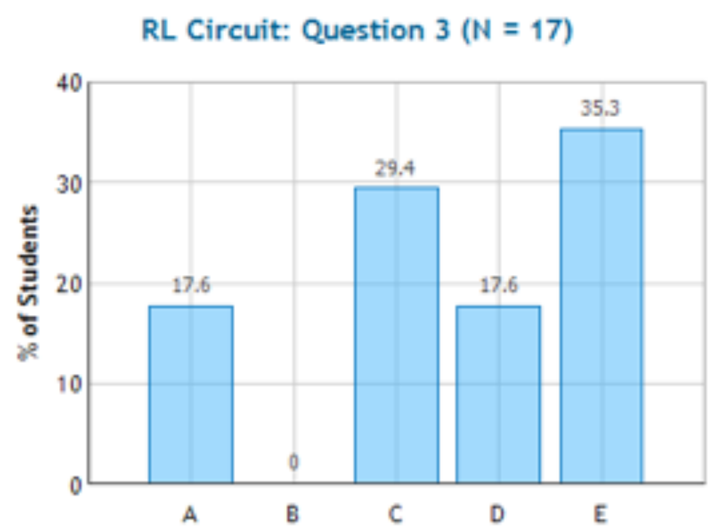
After a long time, the switch is opened, abruptly disconnecting the battery from the circuit.

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



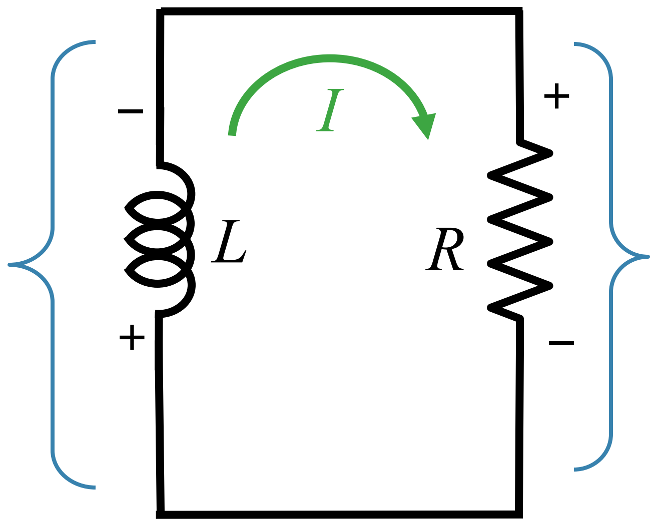

(+ is in the direction of the arrow)

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

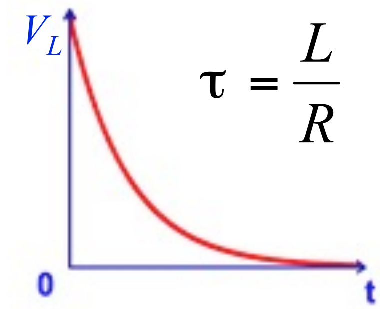


# Why is there Exponential Behavior?

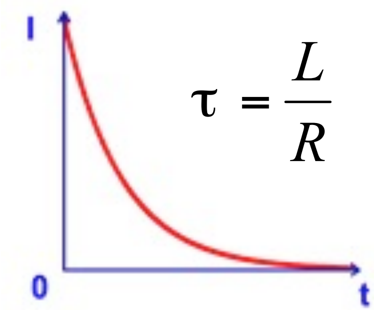
$$V = L\frac{dI}{dt}$$




$$V = IR$$




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

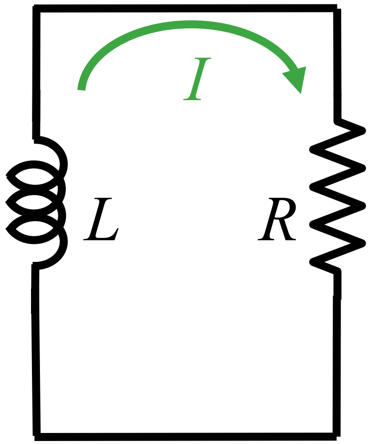


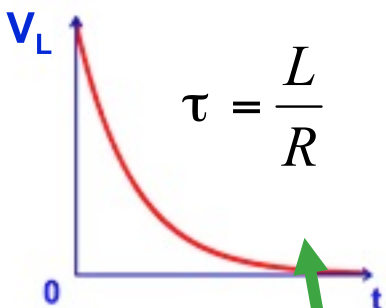

$$\tau = \frac{L}{R}$$

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

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

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

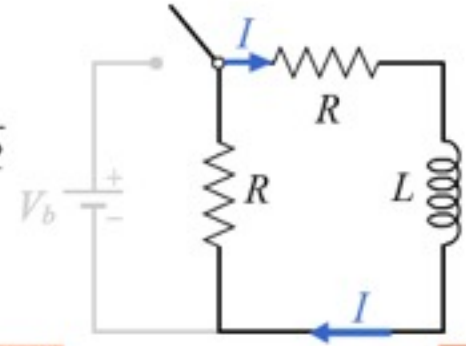


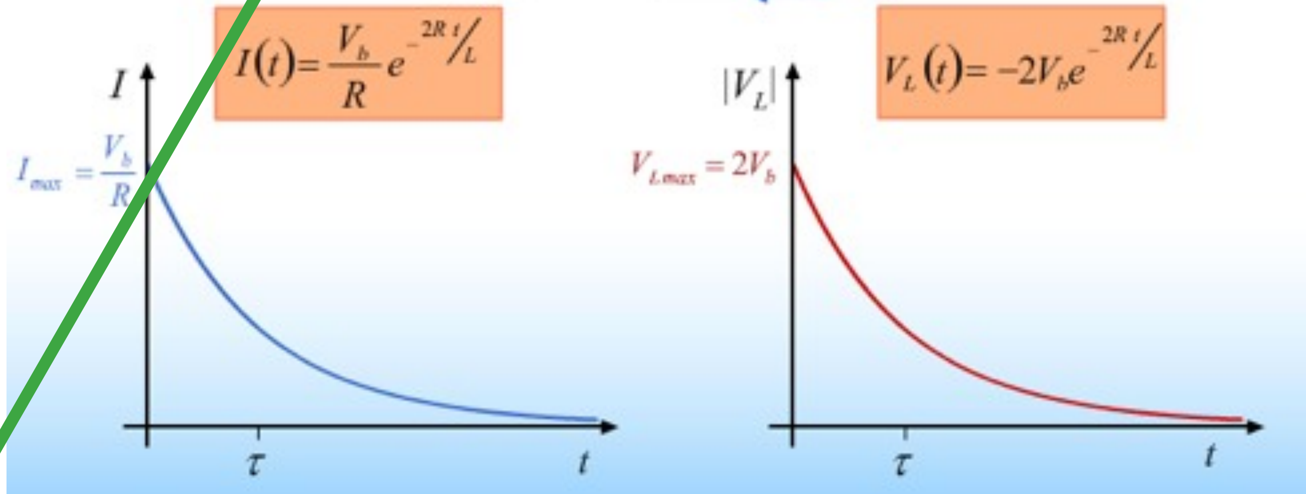




$$\tau = \frac{L}{R}$$

Lecture:

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



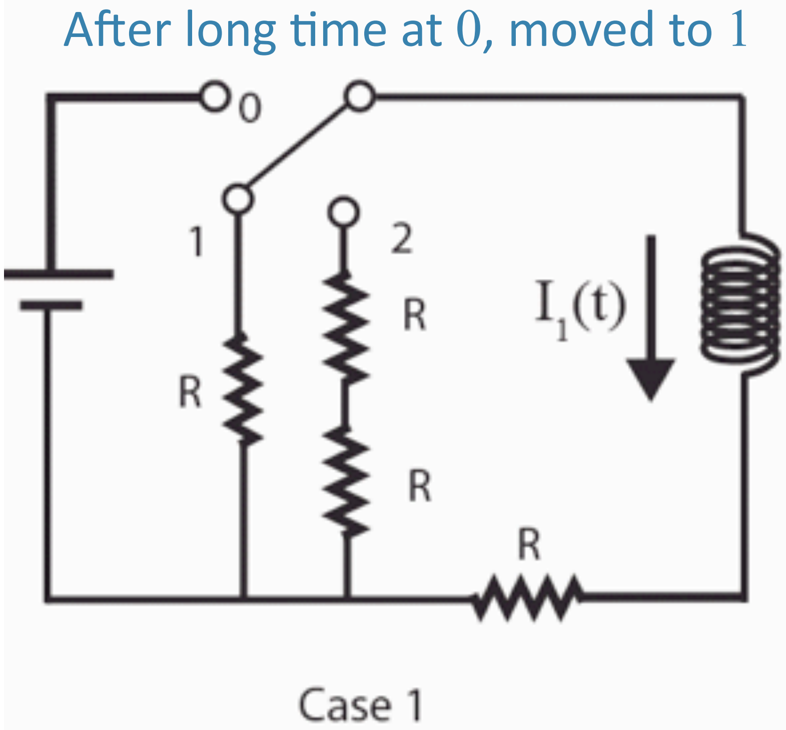



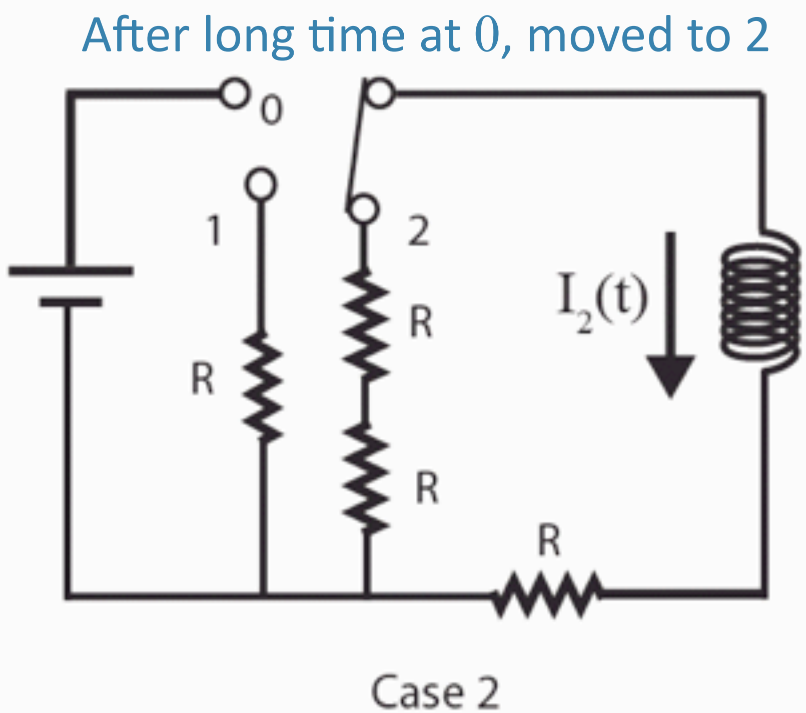

Prelecture:

Did we mess up?

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

# CheckPoint 8

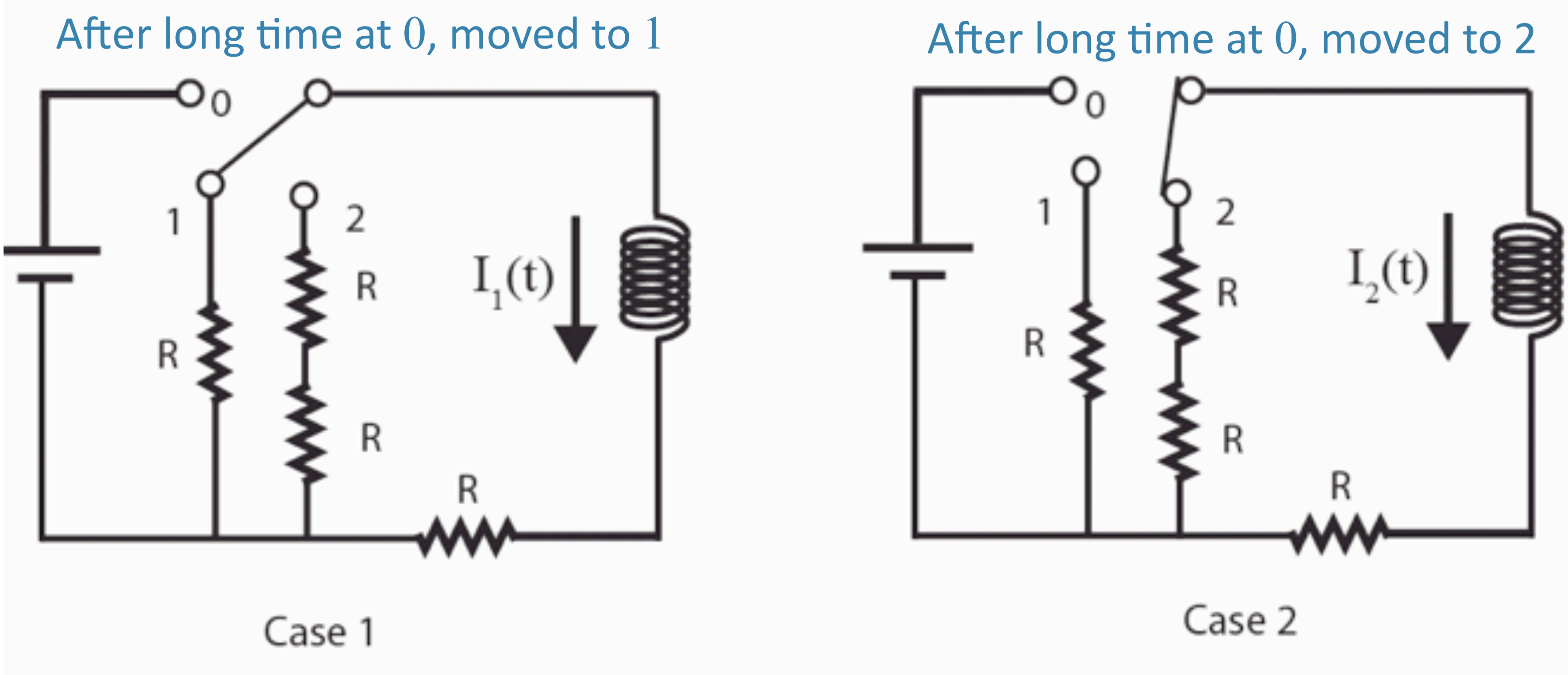



After switch moved, which case has larger time constant?

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

# CheckPoint 10




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

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

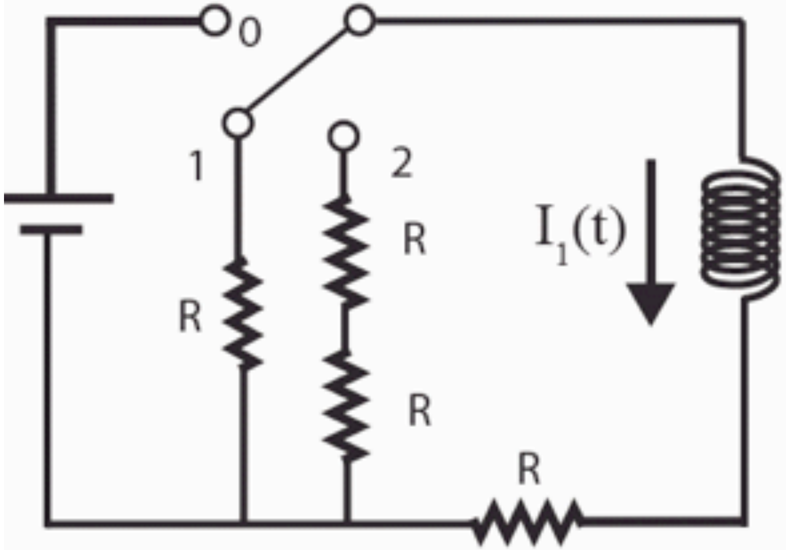
**$I_0$ is V/R in both cases**

**A) $V_L(0) = I_0*2R$**

**B) $V_L(0) = I_0*3R$**

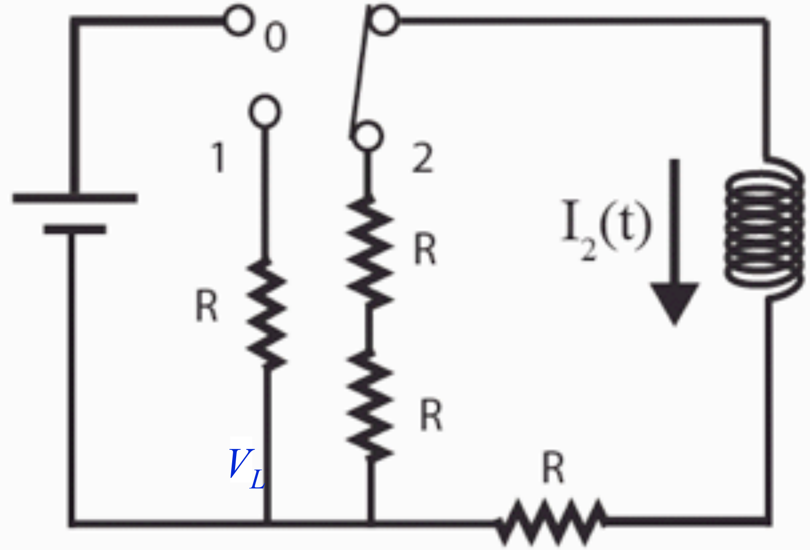
# CheckPoint 12

After long time at 0, moved to 1




Case 1

After long time at 0, moved to 2



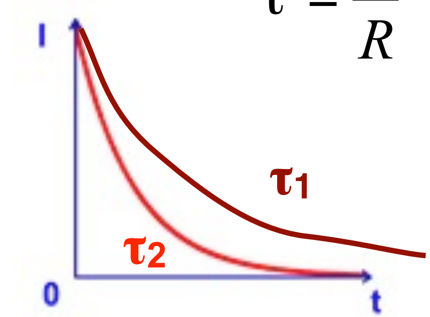

Case 2

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

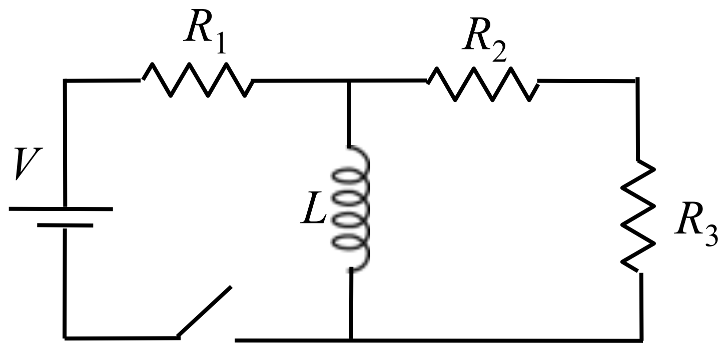
A) $\tau_1 = L/2R$
B) $\tau_2 = L/3R$

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



# 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

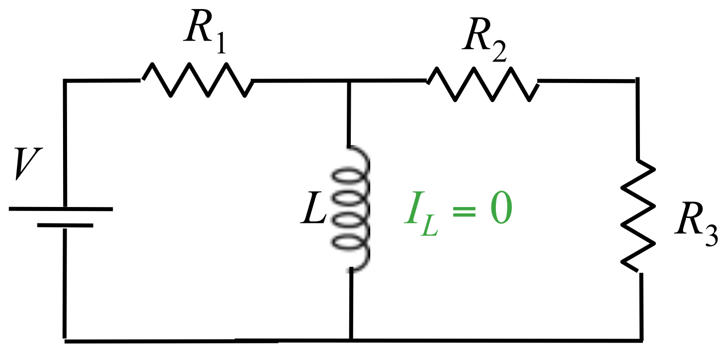
Determine currents immediately after switch is closed.

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?

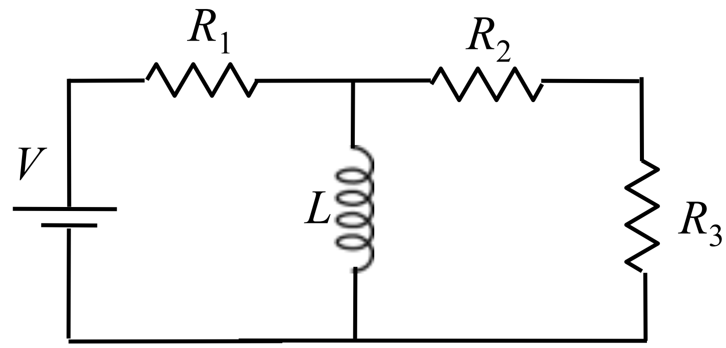
A) $I_L = V/R_1$ up

B) $I_L = V/R_1$ down

C) $I_L = 0$

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

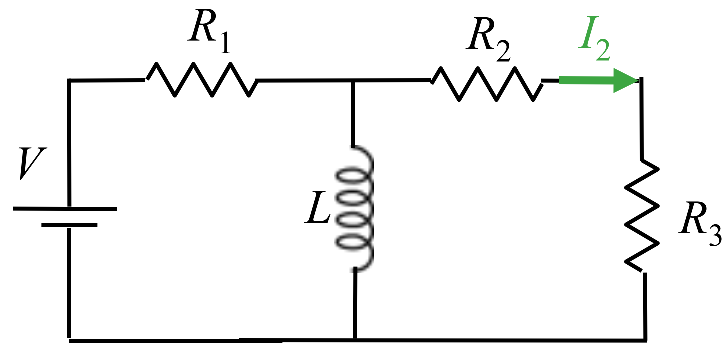
B) $I_2 = \dfrac{V}{R_2 + R_3}$

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

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

# Calculation

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




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

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) $V_L = 0$

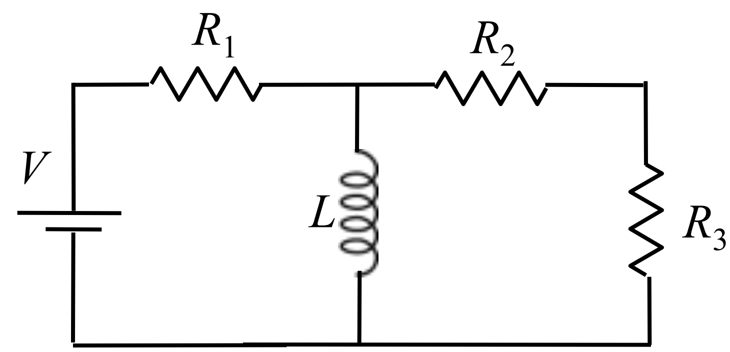
D) $V_L = V\dfrac{R_2R_3}{R_1(R_2+R_3)}$

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

# Calculation

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

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

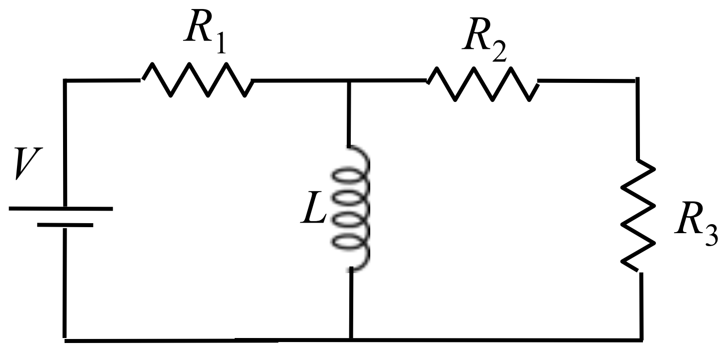
B) $\frac{dI_L}{dt} = 0$

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

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

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

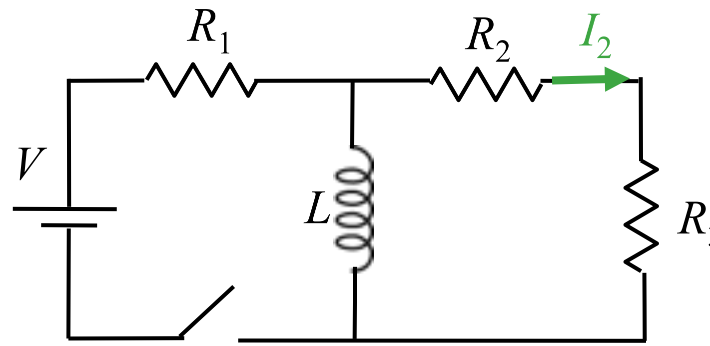
B) $I_2 = +\frac{V(R_2 R_3)}{R_1 + R_2 + R_3}$

C) $I_2 = 0$

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

# 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) $I_2 = -\frac{V}{R_1}$

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