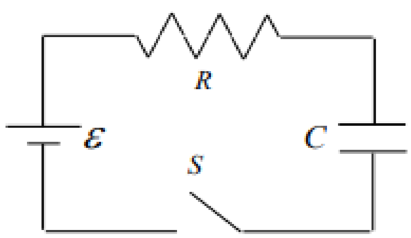
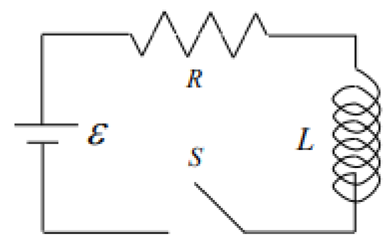
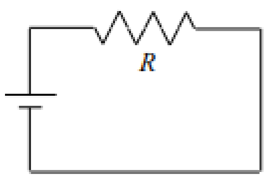
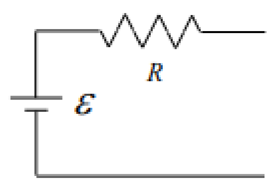
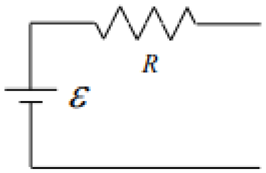
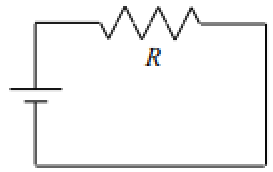
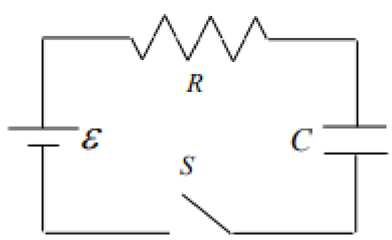
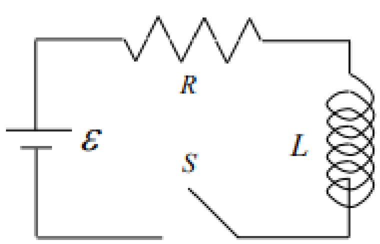
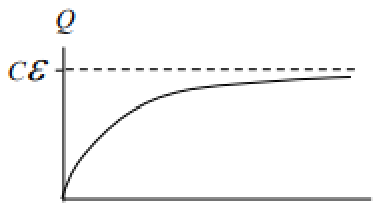
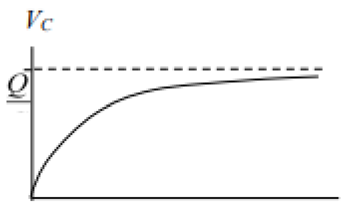
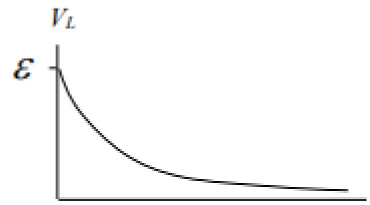
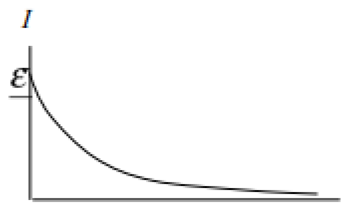
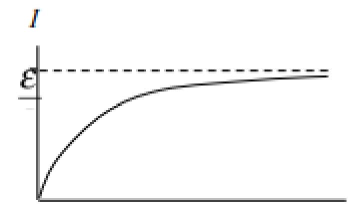
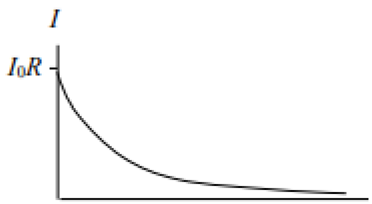
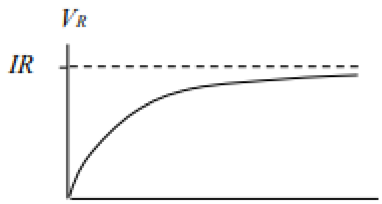
AP Physics C: Mechanics:: Keynotes 2

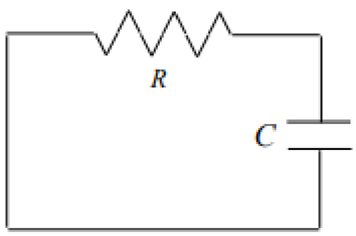
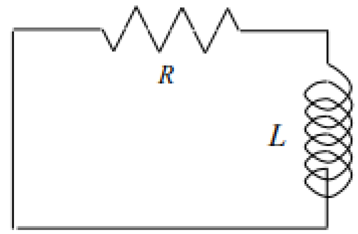
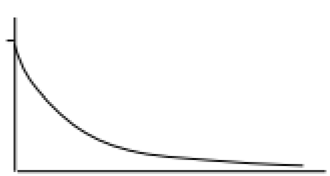
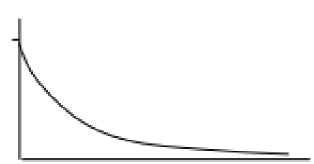
INITIAL AND FINAL CONDITION IN SIMPLE SERIES RC AND LR CIRCUITS			
			
INITIAL CONDITIONS RC CIRCUIT		**INITIAL CONDITIONS LR CIRCUIT**	
Initially the capacitor is uncharged. Capacitors need charge to have voltage (pressure). No pressure means it acts like a wire. 	Capacitor is uncharged $Q = 0$ $C = \frac{Q}{V_C}$ then $V_C = \frac{Q}{C} = \frac{0}{C}$ $V_C = 0$	Initially the inductor creates a back *emf* equal to the batteries *emf*. This opposite pressure stops current. The inductor acts like a wall or gap in the circuit. 	Inductor stops current $I = 0$ $V_R = IR$ $V_R = (0)R$ $V_R = 0$
Apply the loop rule The voltage in any loop equals zero.	$\varepsilon - V_R - V_C = 0$ $\varepsilon - V_R - 0 = 0$ $V_R = \varepsilon$	Apply the loop rule The voltage in any loop equals zero.	$\varepsilon - V_R - V_L = 0$ $\varepsilon - 0 - V_L = 0$ $V_L = \varepsilon$
Since this is at the beginning of the problem we are solving for the initial current.	$I_0 R = \varepsilon$ $I_0 = \frac{\varepsilon}{R}$		

FINAL CONDITIONS RC CIRCUIT		FINAL CONDITIONS LR CIRCUIT	
After a long the capacitor is charged, and its voltage equals the *emf* of the battery. These opposite pressures result in no current. The capacitor acts like a wall or gap in the circuit 	Capacitor stops current $I = 0$ $V_R = IR$ $V_R = (0)R$ $V_R = 0$	After a long time current becomes constant. There is no change in flux and no voltage (back *emf*) in the inductor. No pressure means the inductor acts like a wire. 	Inductor stops generating back *emf* $V_L = 0$
Apply the loop rule The voltage in any loop equals zero.	$\varepsilon - V_R - V_C = 0$ $\varepsilon - 0 - V_C = 0$ $V_C = \varepsilon$	Apply the loop rule The voltage in any loop equals zero.	$\varepsilon - V_R - V_L = 0$ $\varepsilon - V_R - 0 = 0$ $V_R = \varepsilon$
This is the end of the problem, so we are solving for the final charge stored on the capacitor.	$\frac{Q}{C} = \varepsilon$ $Q = C\varepsilon$	This is the end of the problem, so we are solving for the final current.	$IR = \varepsilon$ $I = \frac{\varepsilon}{R}$

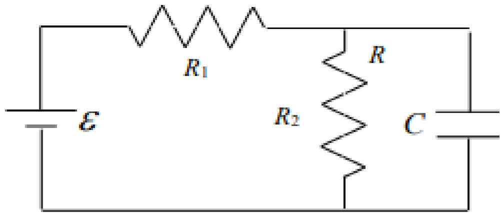
RC	LR
	

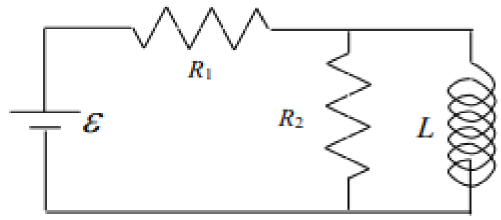
KEY VALUES FROM PREVIOUS PAGE		INITIAL CONDITIONS LR CIRCUIT	
Initially when the switch is thrown	$Q = 0$ $V_C = 0$ $I = \frac{\varepsilon}{R}$ $V_R = \varepsilon$	Initially when the switch is thrown	$I = 0$ $V_R = 0$ $V_L = \varepsilon$
After a long time has passed	$Q = C\varepsilon$ $V_C = \varepsilon$ $I = 0$ $V_R = 0$	After a long time has passed	$I = \frac{\varepsilon}{R}$ $V_R = \varepsilon$ $V_L = 0$

BETWEEN INITIAL AND FINAL CONDITIONS B		BETWEEN INITIAL AND FINAL CONDITIONS	
Time Constant	$\tau = RC$	Time Constant	$\tau = \frac{L}{R}$
Charge on capacitor $Q_{(t)} = Q(1 - e^{-\frac{1}{\tau}})$ $Q_{(t)} = C\varepsilon(1 - e^{-\frac{1}{\tau}})$			
Voltage of capacitor $V_{C(t)} = V_C\left(1 - e^{-\frac{1}{\tau}}\right)$ $V_{C(t)} = \frac{Q}{C}(1 - e^{-\frac{1}{\tau}})$		Voltage of inductor $V_{L(t)} = V_{L0}e^{-\frac{1}{\tau}}$ $V_{L(t)} = \varepsilon e^{-\frac{1}{\tau}}$	
Current in resistor $I_{(t)} = I_0 e^{-\frac{1}{\tau}}$ $I_{(t)} = \frac{\varepsilon}{R}e^{-\frac{1}{\tau}}$		Current in resistor $I_{(t)} = I(1 - e^{-\frac{1}{\tau}})$ $I_{(t)} = \frac{\varepsilon}{R}(1 - e^{-\frac{1}{\tau}})$	
Voltage of resistor $V_{R(t)} = V_{R0}e^{-\frac{1}{\tau}}$ $V_{R(t)} = I_0 R e^{-\frac{1}{\tau}}$		Voltage of resistor $V_{g(t)} = V_R(1 - e^{-\frac{1}{\tau}})$ $V_{g(t)} = IR(1 - e^{-\frac{1}{\tau}})$	

<table>
<tr><th colspan="4">REMOVING BATTERY AFTER A STEADY STATE HAS BEEN REACHED</th></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><th colspan="2">CAPACITOR ACTS LIKE A BATTERY</th><th colspan="2">INDUCTOR ACTS LIKE A BATTERY</th></tr>
<tr><td>Removing the battery from the circuit after charging the capacitor begins part II of this problem. The capacitor acts like the battery until it losses all of its energy. The final values for the capacitor in part I become the initial values for the capacitor in part II.</td><td>$Q = C\varepsilon$
$V_C = \varepsilon$</td><td>Removing the battery from the circuit after a constant current is established begins part II of this problem. The final current reached in part I becomes the initial current in part II. This current is moving through the resistor, so its final values in part I also transfer to part II.</td><td>$I = \frac{\varepsilon}{R}$
$V_R = \varepsilon$</td></tr>
<tr><td>Apply the loop rule The voltage in any loop equals zero.</td><td>$V_C = V_R = 0$
$V_C = V_R$</td><td>Apply the loop rule The voltage in any loop equals zero.</td><td>$V_L - V_R = 0$
$V_L = V_R$</td></tr>
<tr><td>Since this is at the beginning of the problem we are solving for the initial current.</td><td>$\frac{Q}{C} = I_0 R$
$I_0 = \frac{Q}{RC}$
$I_0 = \frac{Q}{\tau}$</td><td></td><td>$L\frac{dl}{dt}$
$dt = \frac{L}{R}$
$\tau = \frac{L}{R}$</td></tr>
<tr><td colspan="2">As current moves through the circuit the charge and energy of the capacitor deminish. The energy is lost as heat through the resistor</td><td colspan="2">As current moves through the circuit the energy of the inducto deminishes. The energy is lost as heat through the resistor</td></tr>
<tr><td>All graphes approach zero.</td><td></td><td>All graphes approach zero.</td><td></td></tr>
<tr><td>All quantities change according to the function</td><td>$Q_{(t)} = Qe^{-\frac{1}{\tau}}$
$V_{C(t)} = \frac{Q}{C}\, e^{-\frac{1}{\tau}}$
$I_{(t)} = \frac{\varepsilon}{R}\, e^{-\frac{1}{\tau}}$
$V_{g(t)} = I_0 R\, e^{-\frac{1}{\tau}}$</td><td>All quantities change according to the function
$Y_{(t)} = Y_0 e^{-\frac{1}{\tau}}$</td><td>$V_{L(t)} = \varepsilon e^{-t/\tau}$
$I_{(t)} = \frac{\varepsilon}{R} e^{-t/\tau}$
$V_{R(t)} = I_0 R e^{-t/\tau}$</td></tr>
</table>

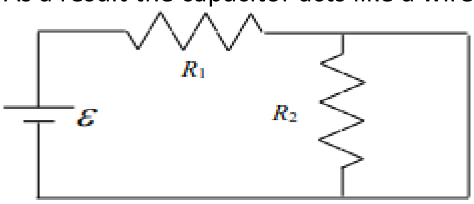
ANALYZING CURRENT IN RC AND LR CIRCUITS WITH PARALLEL PATHWAYS





INITIAL CONDITIONS RC CIRCUIT

Initially the capacitor is uncharged, and there is no voltage the capacitor. As a result the capacitor acts like a wire.

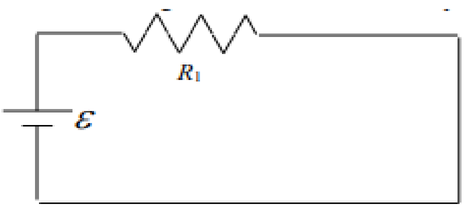


The charges must go through R_1 . In parallel the ratio of current in each path is the opposite of the ratio of resistance. The ratio of resistance is R_2 : nearly 0. Therefore the ratio of current will be nearly 0 in the resistor: I through the wire. The current is pushed through the wire.

Initial current

$\mathcal{E} = I_0 R_1$

$$\boxed{I_0 = \frac{\mathcal{E}}{R_1}}$$



INITIAL CONDITIONS LR CIRCUIT

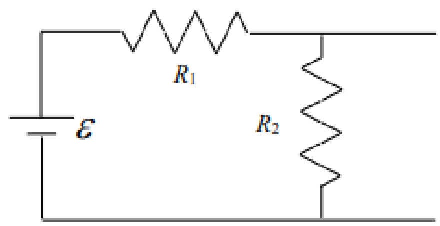
Initially the inductor creates a back *emf* equal to the batteries *emf*. This opposite pressure stops current. The inductor acts like a wall or gap in the circuit.

Initial current

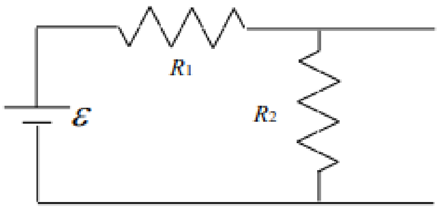
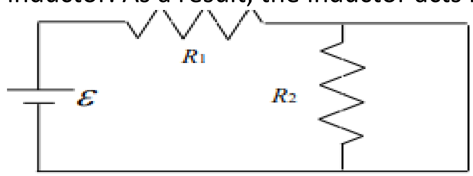
$R_s = R_1 + R_2$

$\mathcal{E} = I_0 (R_1 + R_2)$

$$I_0 = \frac{\mathcal{E}}{(R_1 + R_2)}$$



<table>
<tr><th>FINAL CONDITIONS RC CIRCUIT</th><th>FINAL CONDITIONS LR CIRCUIT</th></tr>
<tr><td rowspan="2">After a long the capacitor is charged, and its voltage equals the emf of the battery. These opposite pressures result in no current. The capacitor acts like a wall or gap in the circuit.

Final current
$R_s = R_1 + R_2$
$\varepsilon = I\left(R_1 + R_2\right)$
$I = \frac{\varepsilon}{\left(R_1 + R_2\right)}$

</td>
<td>After a long time current becomes constant. There is no change in flux and no voltage (back emf) across the inductor. As a result, the inductor acts like a wire.

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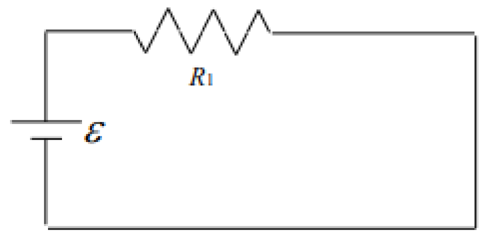
<tr><td>The charges must go through R_1. In parallel the ratio of current in each path is the opposite of the ratio of resistance. The ratio of resistance is R_2: nearly 0. Therefore the ratio of current will be nearly 0 in the resistor: I through the wire. The current is pushed through the wire.

Final current
$\varepsilon = IR_1$
$\boxed{I = \frac{\varepsilon}{R_1}}$

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