PHYSICS 1B – Fall 2009

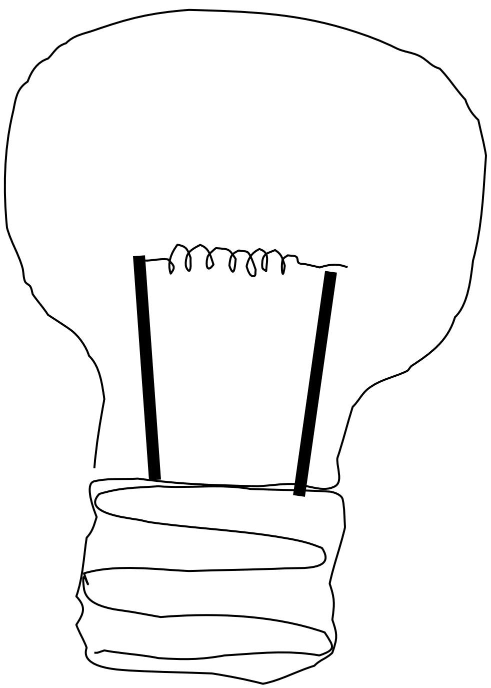
Electricity
&
Magnetism

Professor Brian Keating

SERF Building. Room 333

Wednesday, November 4, 2009

Resistance of a light bulb filament.



Thin tungsten coil.

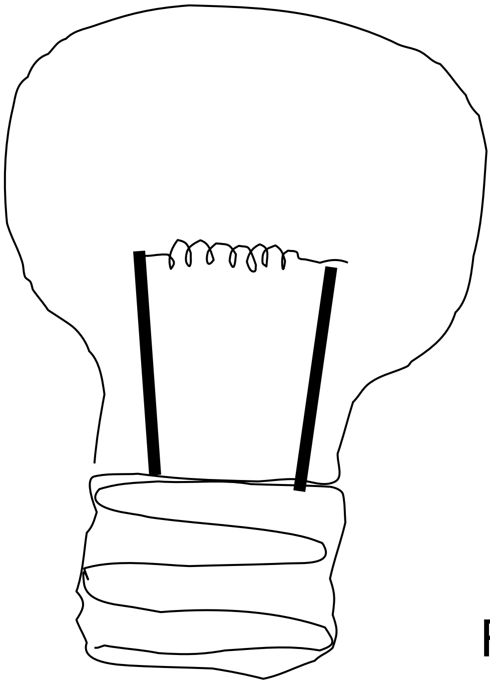
$R = 150\ \Omega$

$\rho = 73 \times 10^{-8}\ \Omega\text{–m}$ (at 2000 C)

$L = 0.5$ m

Find the diameter of the wire.

Resistance of a light bulb filament.



Thin tungsten coil.

R=150 Ω
ρ =73 x10^{-8} Ω–m (at 2000 C)
L=0.5 m

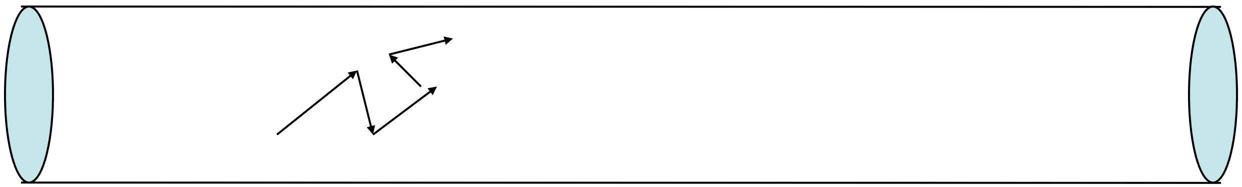
Find the diameter of the wire.

$$R = \frac{\rho L}{A} = \frac{4\rho L}{\pi d^2}$$

$$d = \sqrt{\frac{4\rho L}{\pi R}} = \sqrt{\frac{4(73x10^{-8})(0.5)}{\pi(150)}} = 5.5x10^{-5}\,m$$

55 μm

Ch 17.6
Temperature dependence of resistance metal conductors



At higher T the collisions with the lattice are more frequent.

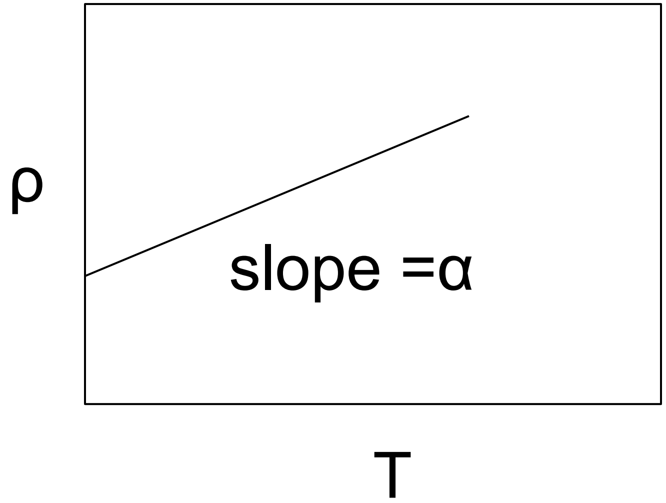
v_D becomes lower

R becomes larger

Temperature coefficient of resistivity

For small changes in T

$$\rho = \rho_o[1+\alpha(T - T_o)]$$



Material	α $(C^o)^{-1}$ near 20^o C
Copper	3.9×10^{-3}
Tungsten	4.5×10^{-3}
Silicon	-7.5×10^{-3}

Thermometry

A platinum resistance thermometer uses the change in resistance to measure temperature. If a student with the flu has a temperature rise of 4.5^{o} C measured with a platinum resistance thermometer and the initial R= 50.00 ohms. What is the final resistance? $\alpha=3.92\times10^{-3}\ {}^{o}C^{-1}$

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$$R \propto \rho$$

$$R = R_o[1 + \alpha(T - T_o)]$$

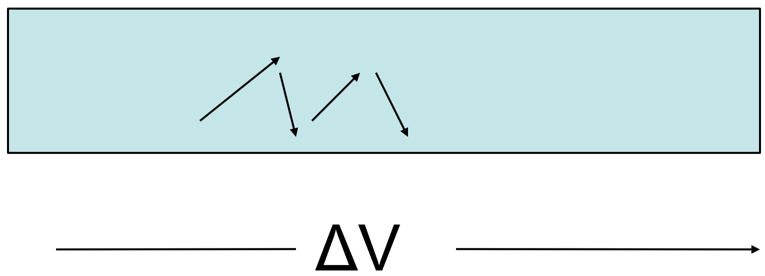
$$R = 50.00[1 + 3.92x10^{-3}(4.5)]$$

$$R = 50.00[1.018] = 50.88\Omega$$

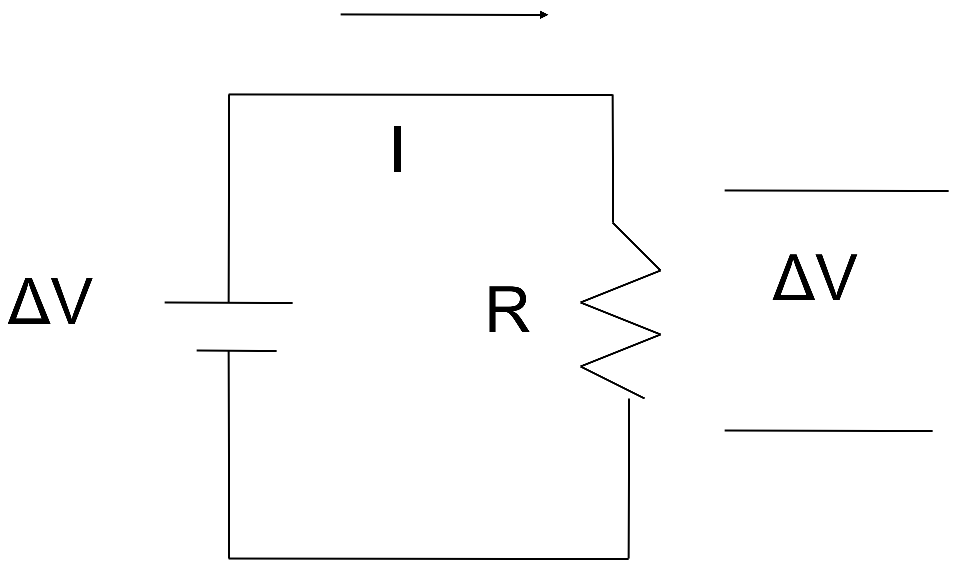
17. 8
Electrical energy, power

The power dissipated in a resistor is due to collisions of charge carriers with the lattice.

Electrical potential energy is converted to Kinetic energy is converted into heat.



Energy dissipated in a resistor



Voltage drop

Change in PE =qΔV

Dissipated as heat

Power dissipated in a resistor

$$P = \frac{work}{time} = \frac{q\Delta V}{\Delta t}$$

Three equivalent relations for the power

Power dissipated in a resistor

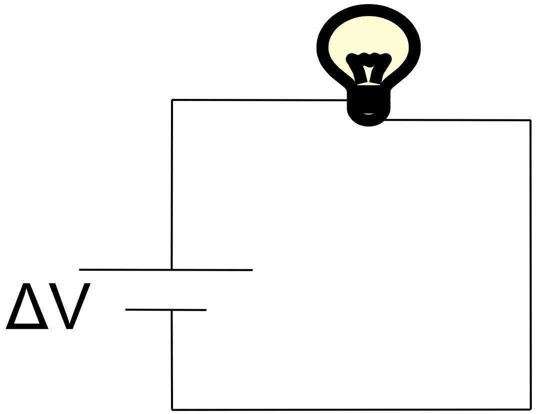
$$P = \frac{work}{time} = \frac{q\Delta V}{\Delta t}$$

$$P = I\Delta V$$

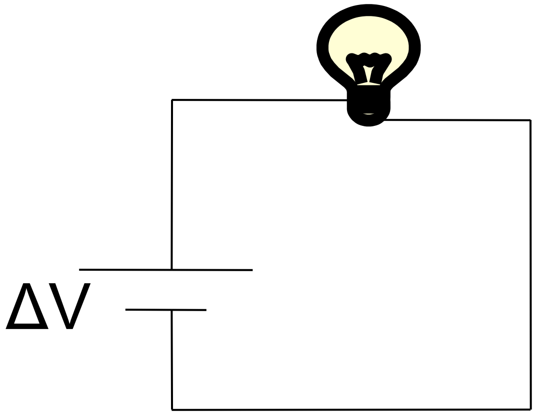
$$P = I(IR) = I^2 R$$

$$P = (\frac{\Delta V}{R})\Delta V = \frac{\Delta V^2}{R}$$

Three equivalent relations for the power



A lightbulb has an output of 100 W when connected to a 120V household outlet. What is the resistance of the filament?



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$$P = \frac{\Delta V^2}{R}$$

$$R = \frac{V^2}{P} = \frac{120^2}{100} = 144\Omega$$

A heating element in an electric range is rated at 2000 W. Find the current required if the voltage is 240 V. Find the resistance of the heating element.

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$$P = IV$$

$$I = \frac{P}{V} = \frac{2000}{240} = 8.3A$$

$$P = I^2R$$

$$R = \frac{P}{I^2} = \frac{2000}{8.3^2} = 29\Omega$$

Cost of electrical power

Kilowatt hour = 1kW x1hr=1000J/s(3600s)=3.6×10^6J

1kW hr costs ~ $0.15

How much does it cost to keep a 100W light on for 24 hrs?

Cost of electrical power

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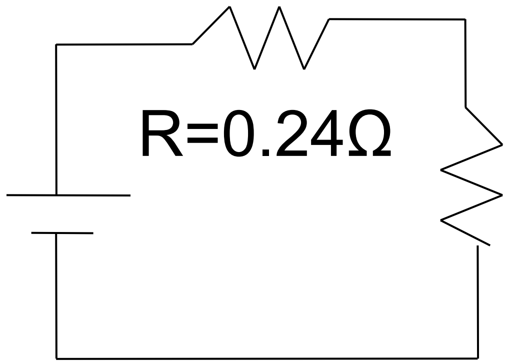
How much does it cost to keep a 100W light on for 24 hrs?

$$Cost = \frac{\$}{kwhr} kwhr = 0.15(0.10)(24) = \$0.36$$

A 10 km copper power cable with a resistance of 0.24 Ω leads from a power plant to a factory. If the factory uses 100 kW of power at a voltage of 120 V how much power would be dissipated in the cable.



P_f=10^5 W

120 V

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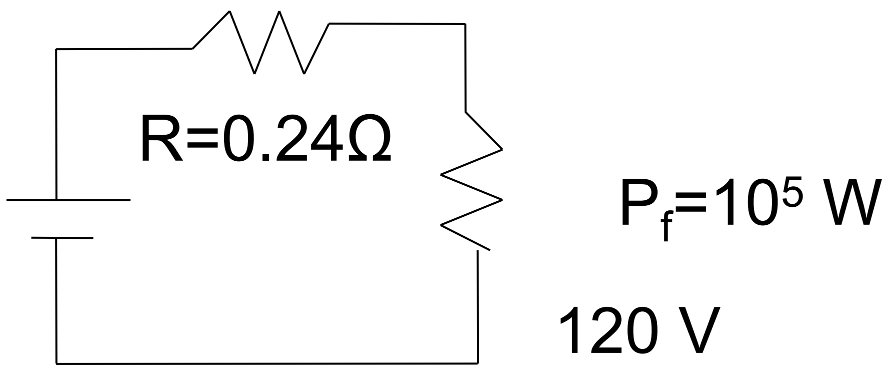

$$P_f = I\Delta V_f$$

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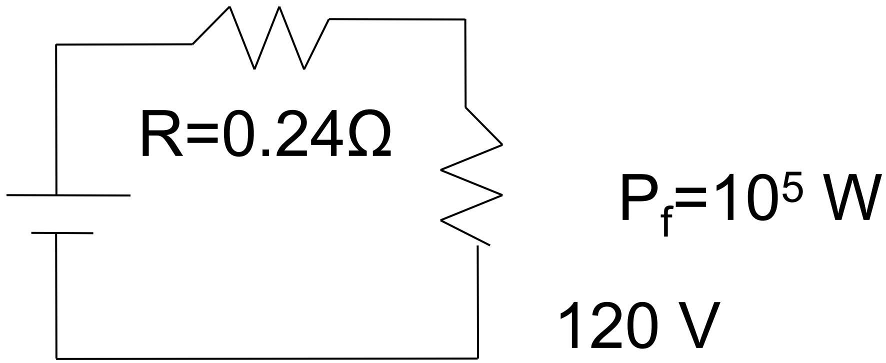

$$P_f = I\Delta V_f$$

$$I = \frac{P_f}{\Delta V_f} = \frac{10^5}{120} = 8.3x10^2\,A$$

A large current is required to provide this power at low voltage

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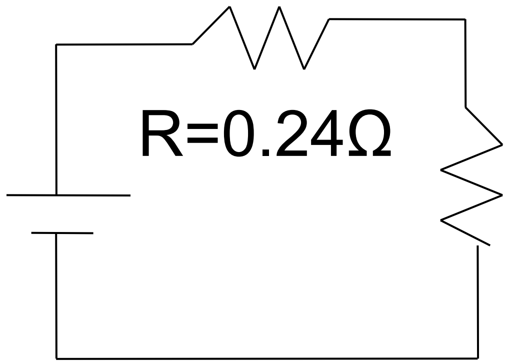

$P_f = 10^5$ W

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A large current is required to provide this power at low voltage

$$P_c = I^2 R_c = (8.3x10^2)^2(0.24) = 1.6x10^5 W$$

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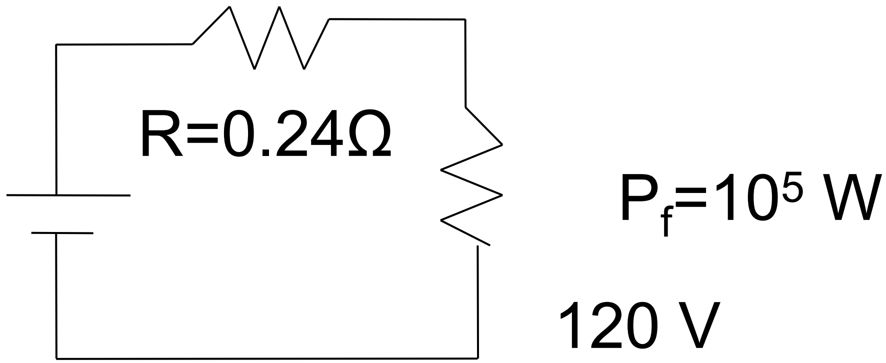

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Very lossy cable

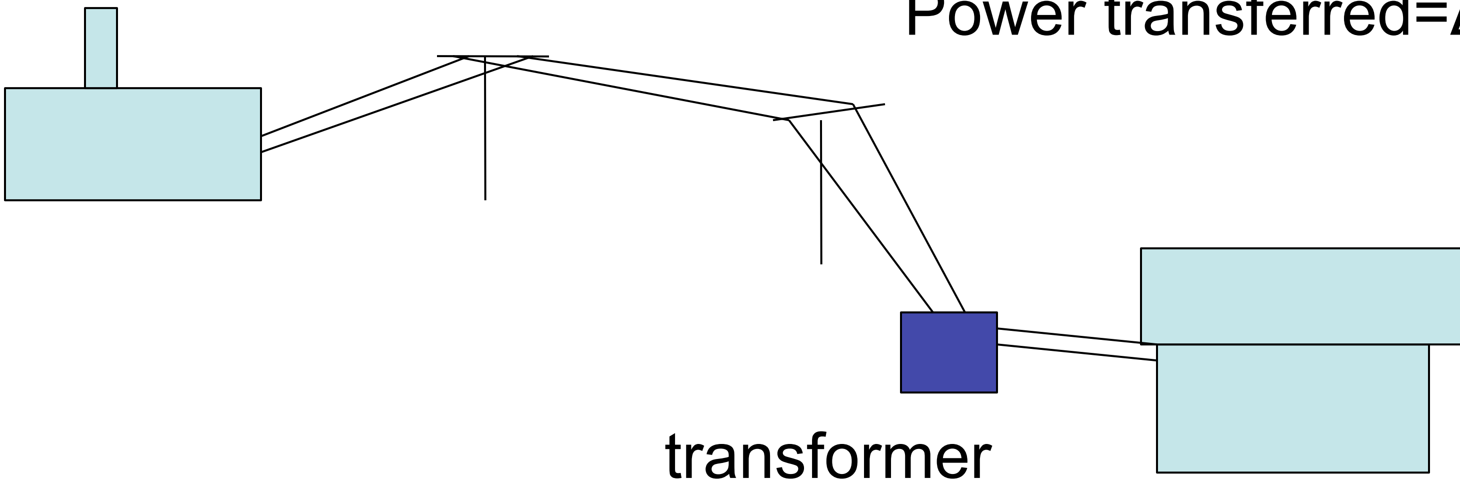
Power Transmission

High voltage

$\Delta V_{trans} = 10^5 V$

Power loss $= I^2 R_{wire}$

Power transferred $= \Delta V_{trans}\, I$



$\Delta V = 120$ V

Low voltage

High voltage transmission- power transmitted with lower current. Therefore lower I^2R loss in the line.

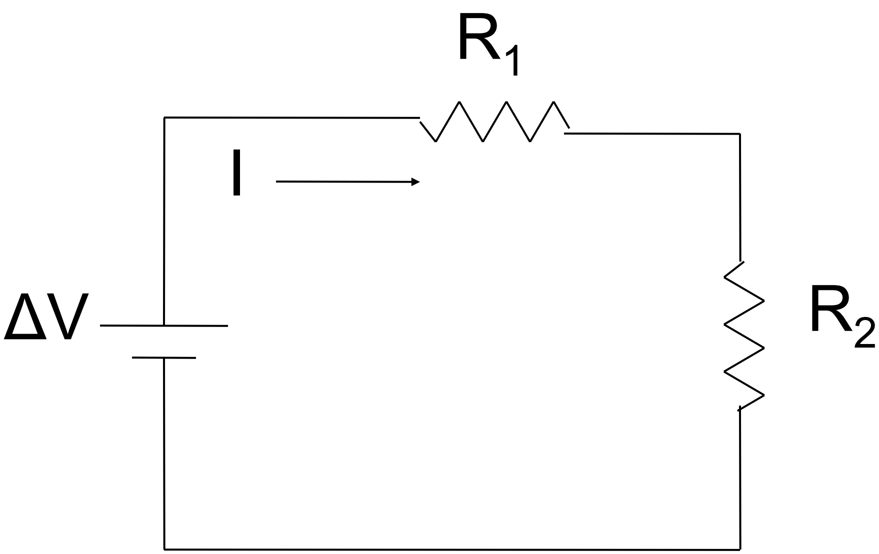
Chapter 18

- Resistors in Series
- Resistors in Parallel
- Combinations of Parallel and Series
- Combinations of Capacitors and Resistors

Ch 18. 2

Resistors in Series

What is the equivalent resistance R_{eq} ?



I same, ΔV different

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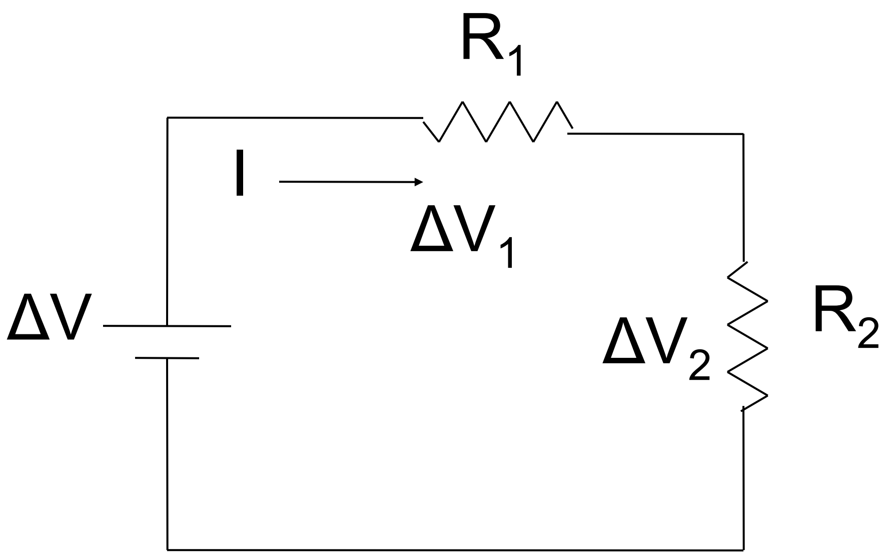

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$\Delta V = \Delta V_1 + \Delta V_2$

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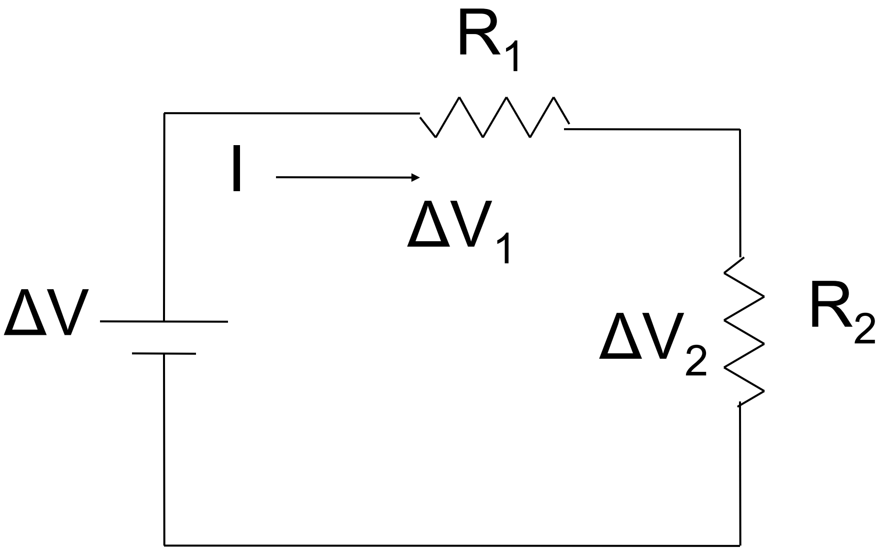

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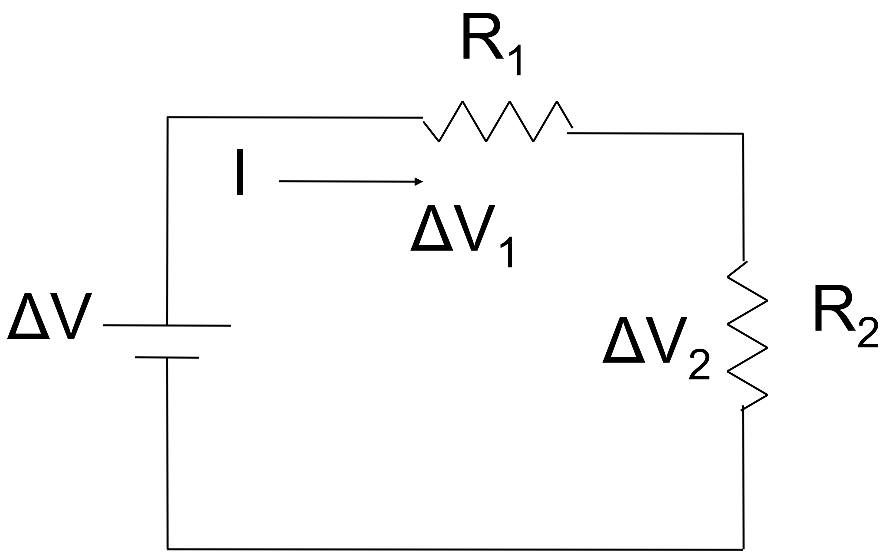

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$$R_{eq} = R_1 + R_2$$

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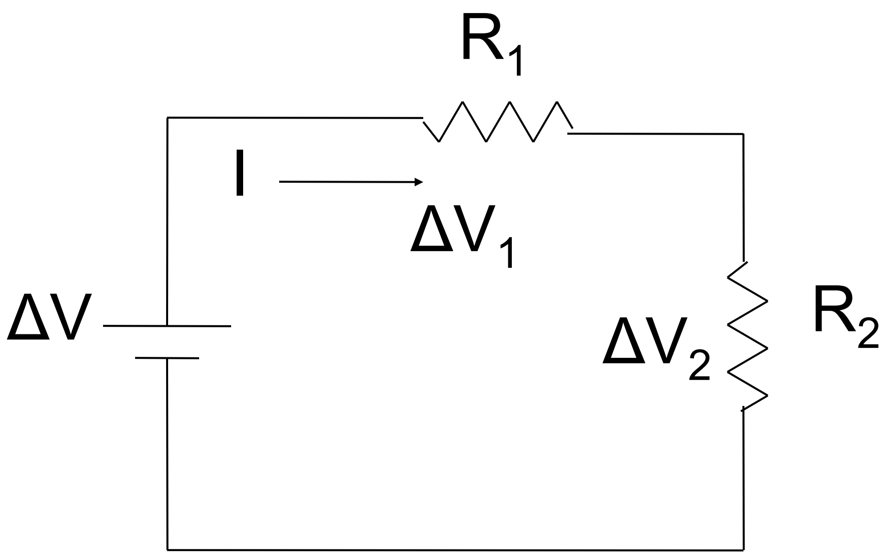

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$\Delta V = IR_{eq} = IR_1 + IR_2$

$R_{eq} = R_1 + R_2$

For N resistors in series

$R_{eq} = R_1 + R_2 + \ldots\ldots R_N$

R_{eq} is larger than any R

Why is the series law easy to understand?

- Recall that the resistance of a resistor is

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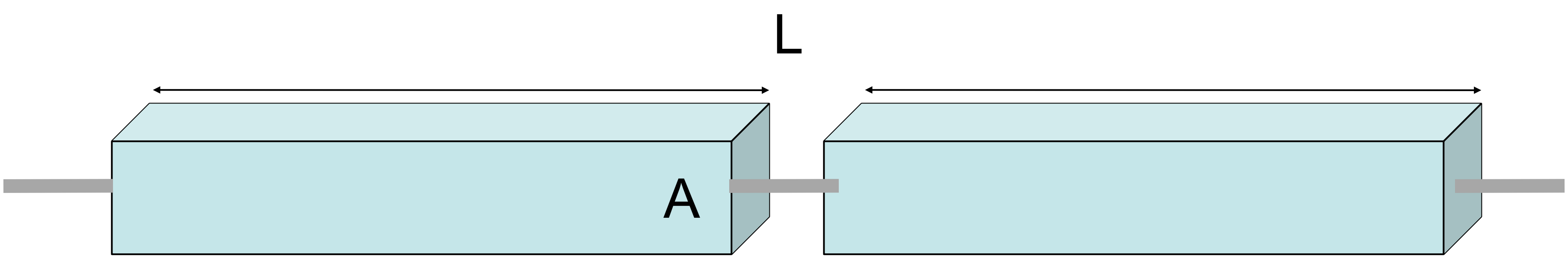
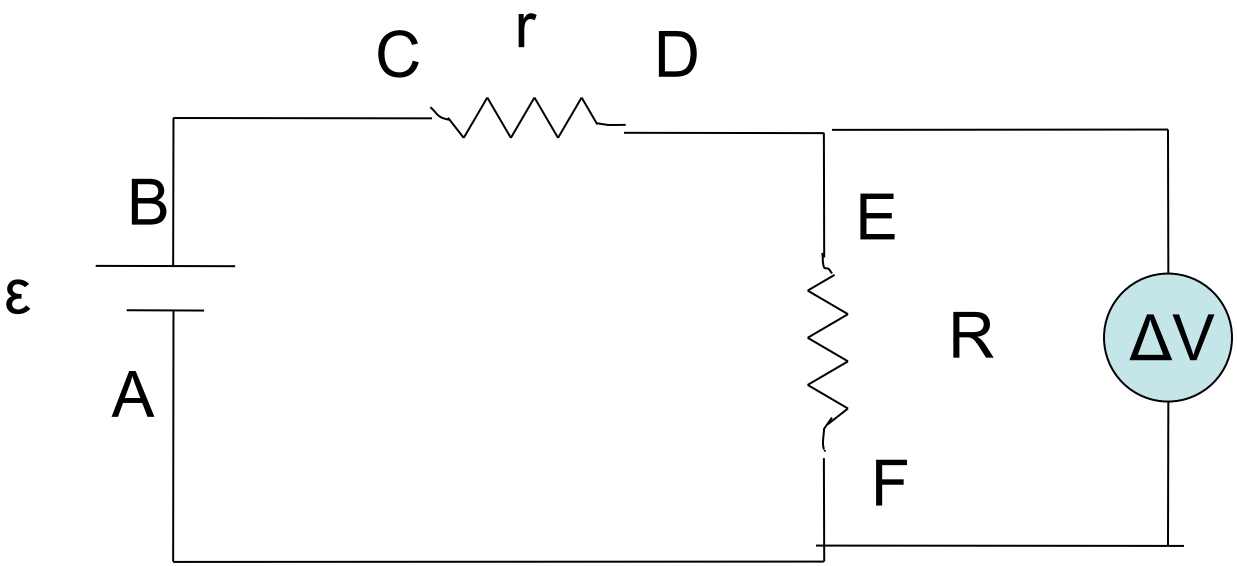


R~L

$R_{tot} \sim L_1 + L_2$

Why do we care?

Consider Simple Circuit: Two resistors in Series



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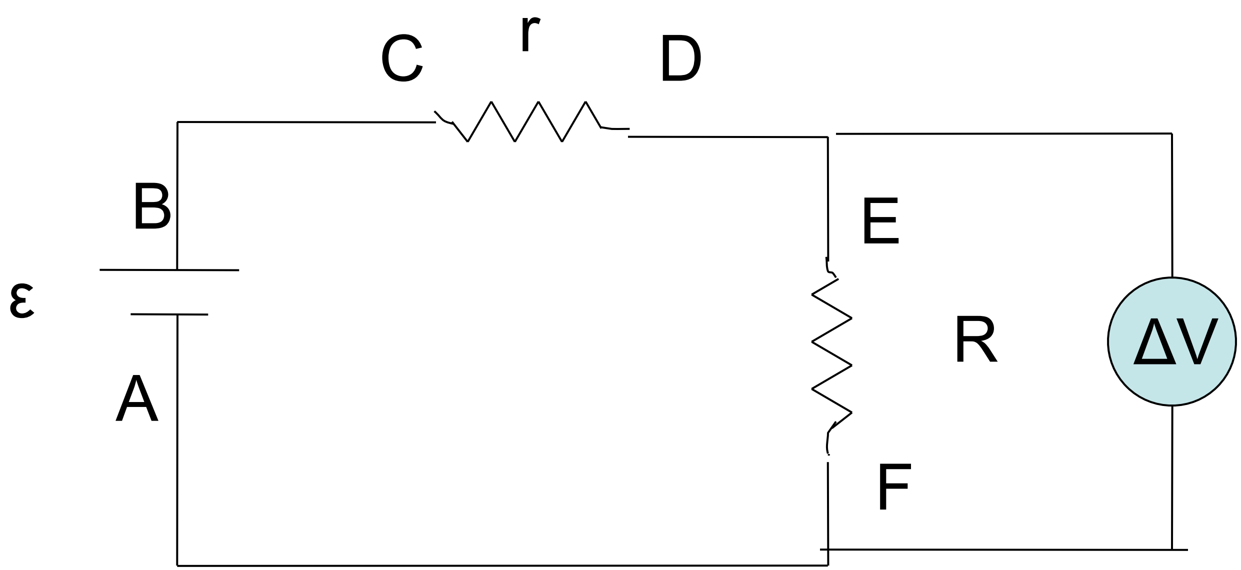

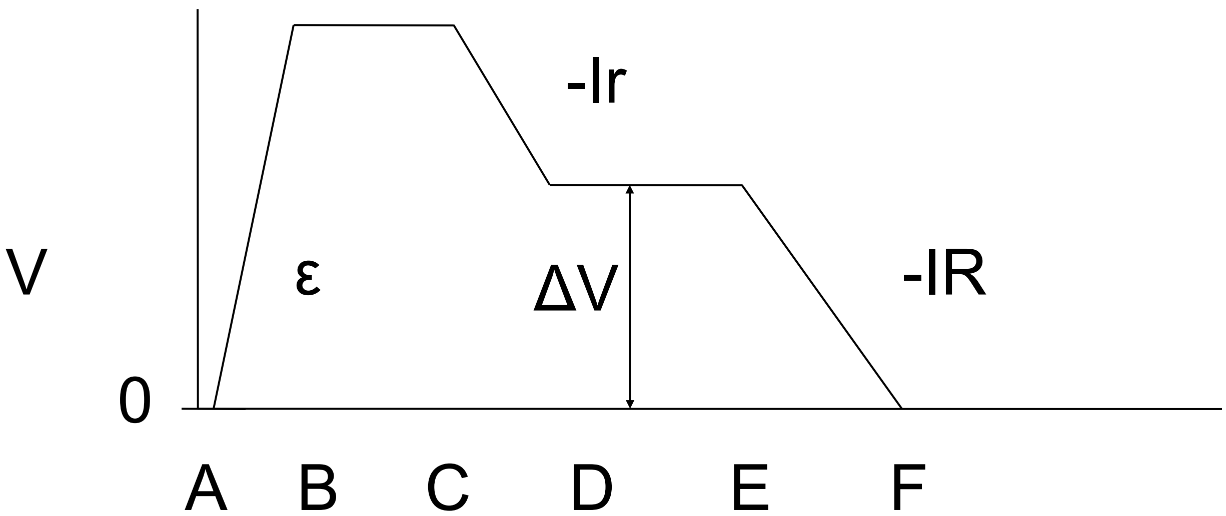

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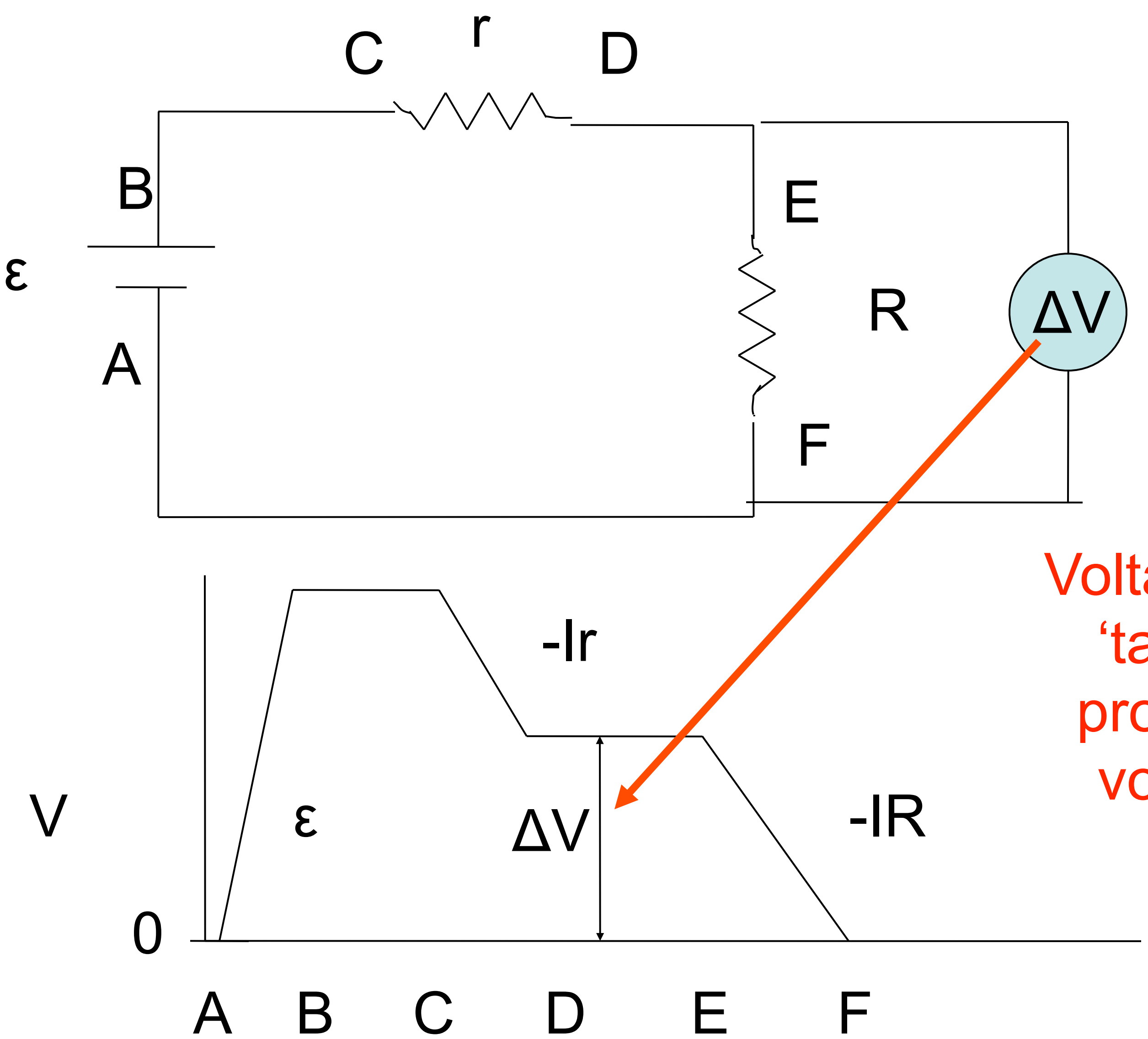
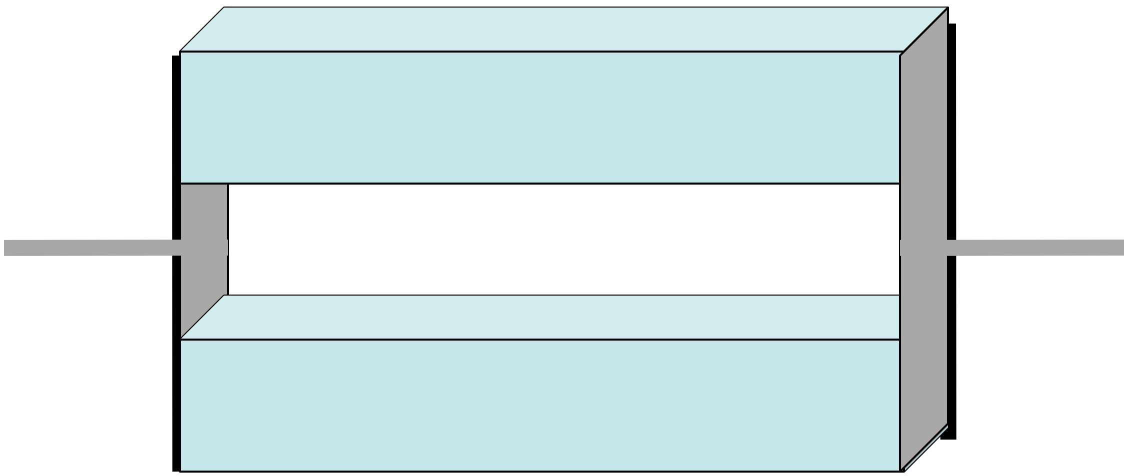


Voltage can be 'tailored' to produce any voltage we desire!

Why is the parallel law easy to understand?

- Recall that the resistance of a resistor is

$$R = \rho \frac{L}{A}$$



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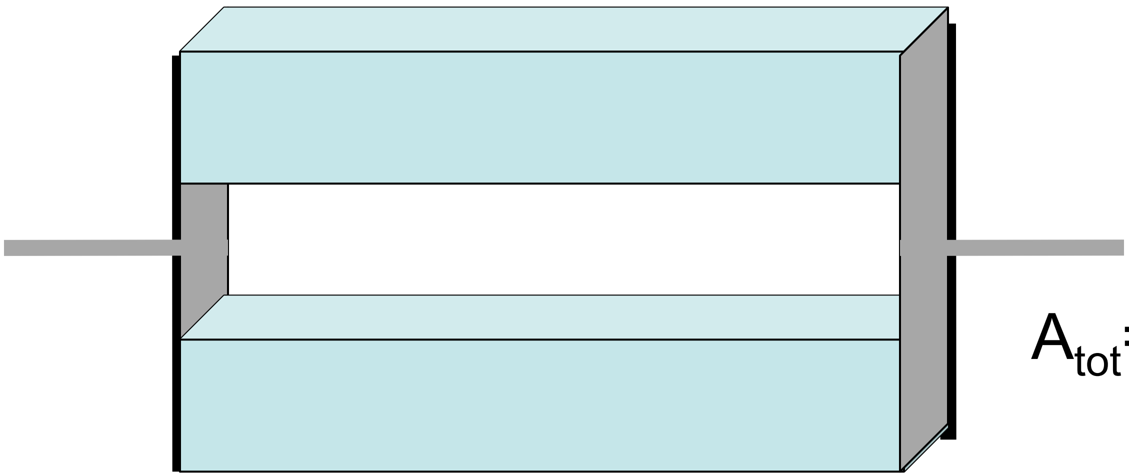

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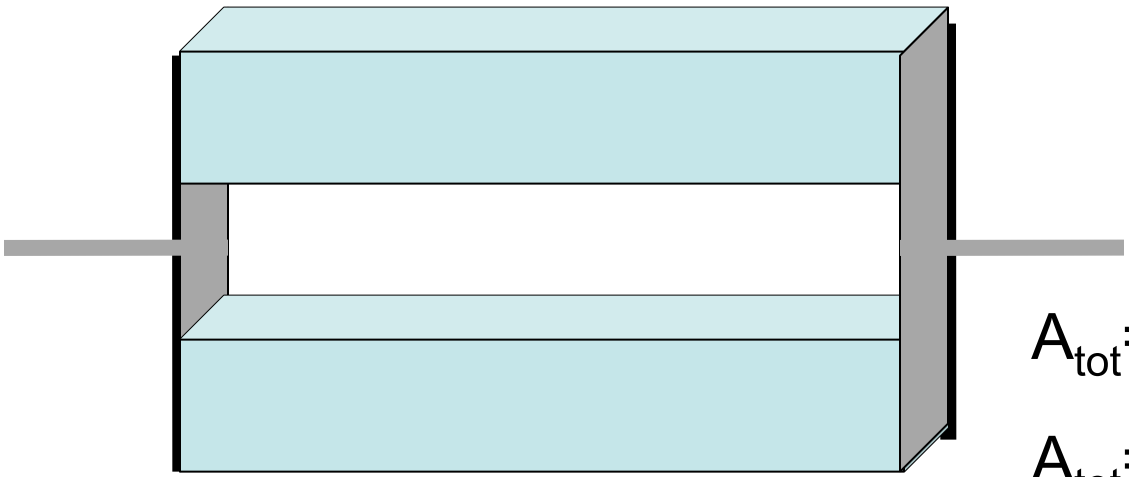

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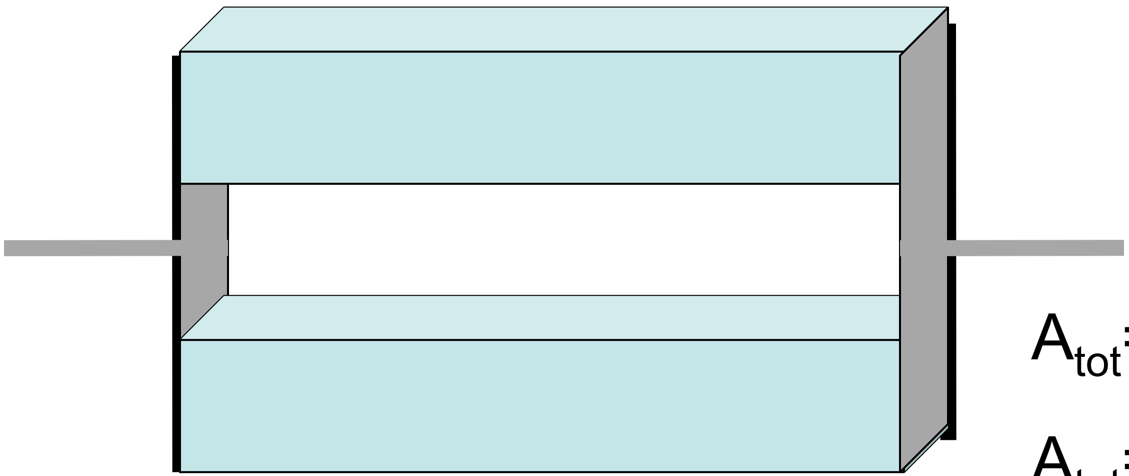

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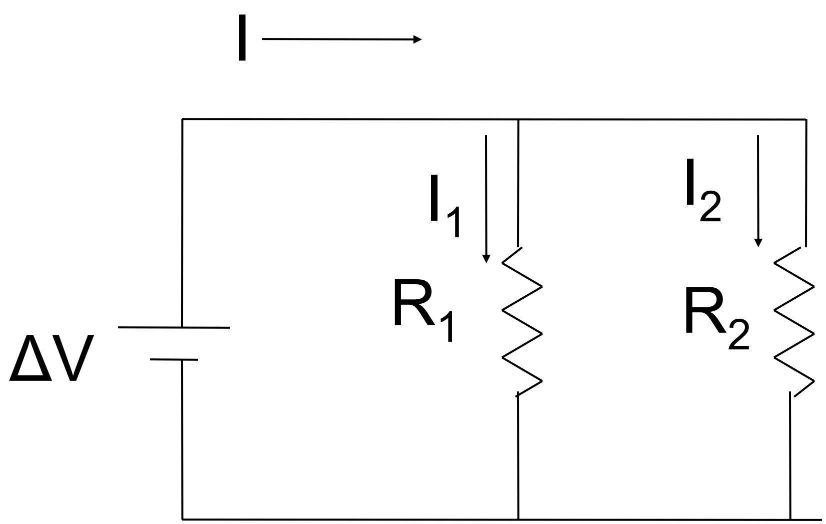
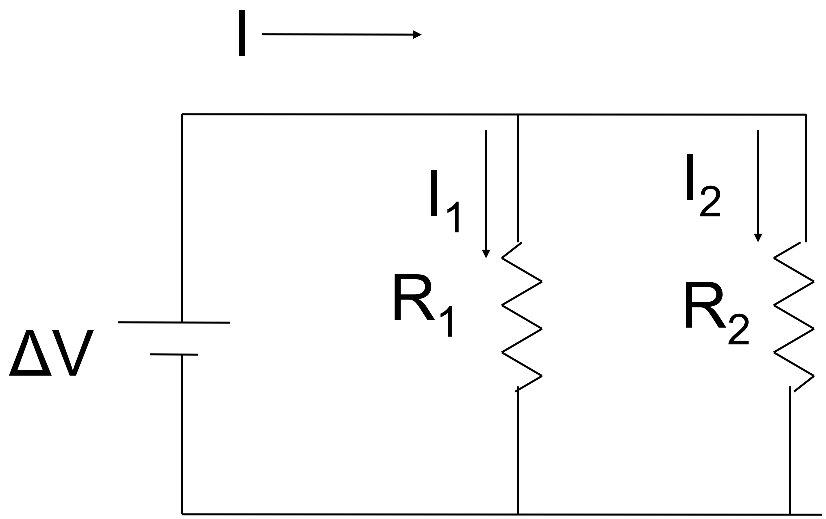
$R_{tot}\sim 1/A_{tot} \sim 1/(1/R_1 + 1/R_2)$

Resistors in parallel, ΔV same, I different



$$I = I_1 + I_2$$

Resistors in parallel, ΔV same, I different



$$I = I_1 + I_2$$

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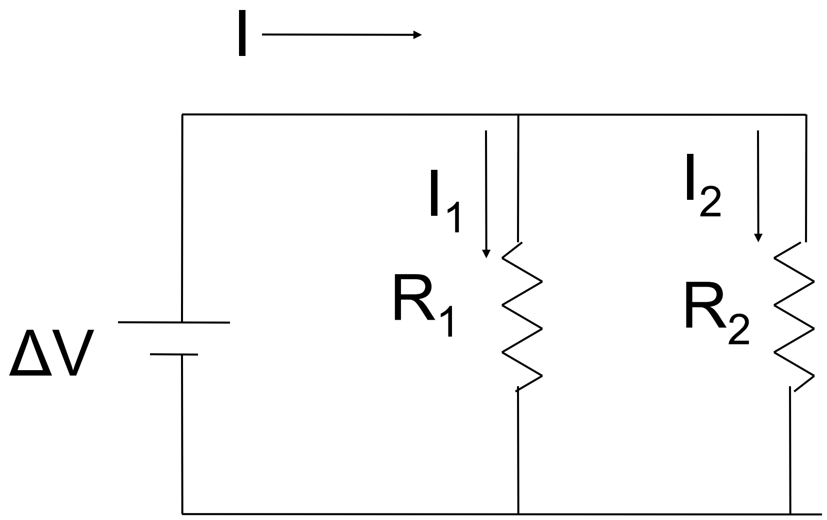

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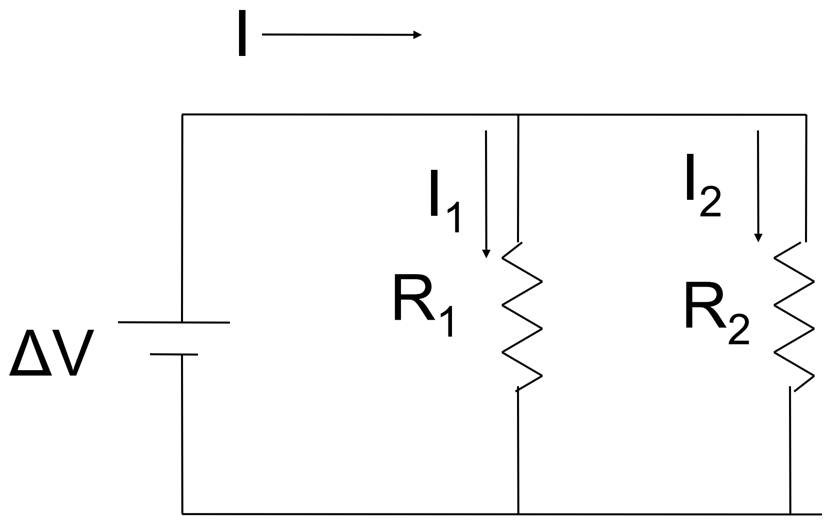

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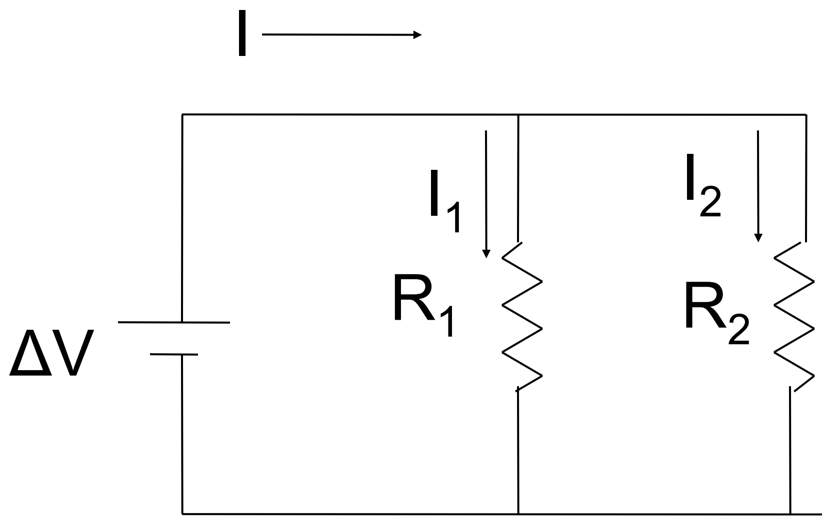

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Monday 11/2

SERF Building. Room 333

Comparisons: Resistors & Capacitors

- Resistors in series are like capacitors in parallel.

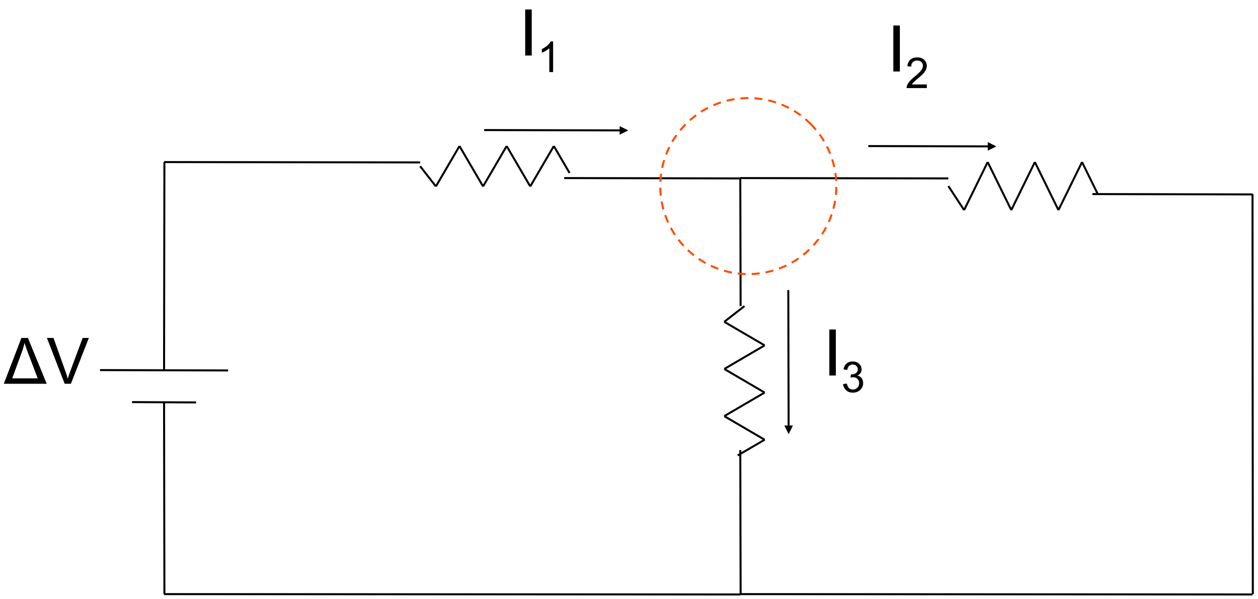
- Resistors in parallel are like capacitors in series.
- This is because R ~ L and C~1/L
- And because R~1/A and C~A

Ch 18 Kirchoff's 2 Rules

1. Junction rule
2. Loop rule

Rule #1. "*Junction rule*"

The current flowing into a junction is equal to the current flowing out.



$$I_1 = I_2 + I_3$$

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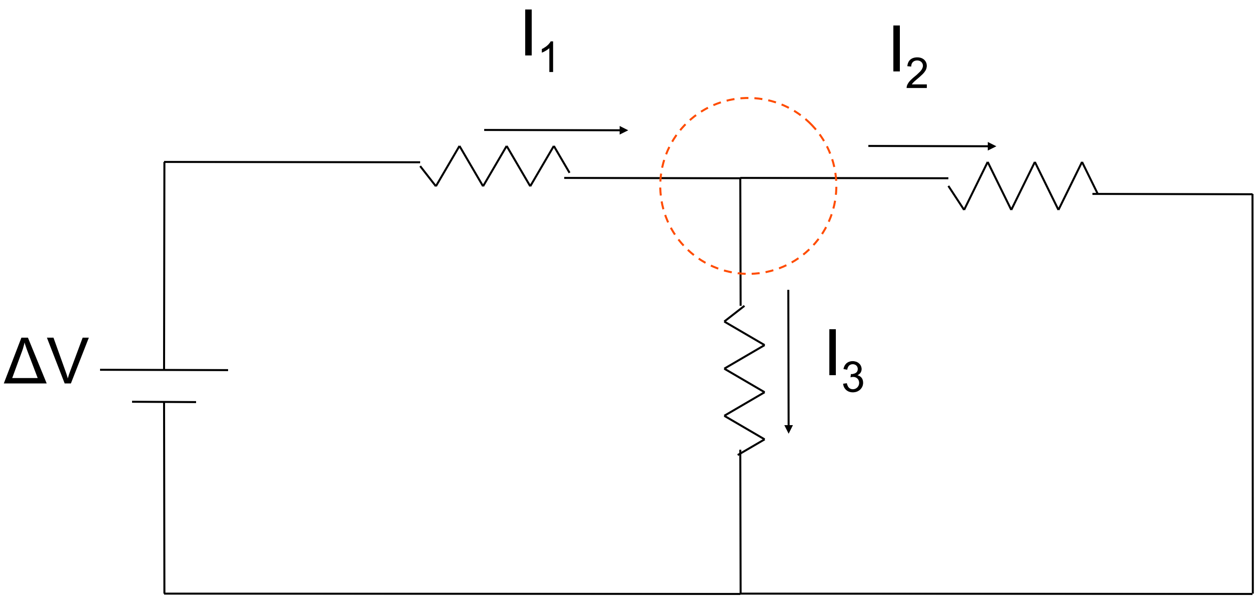
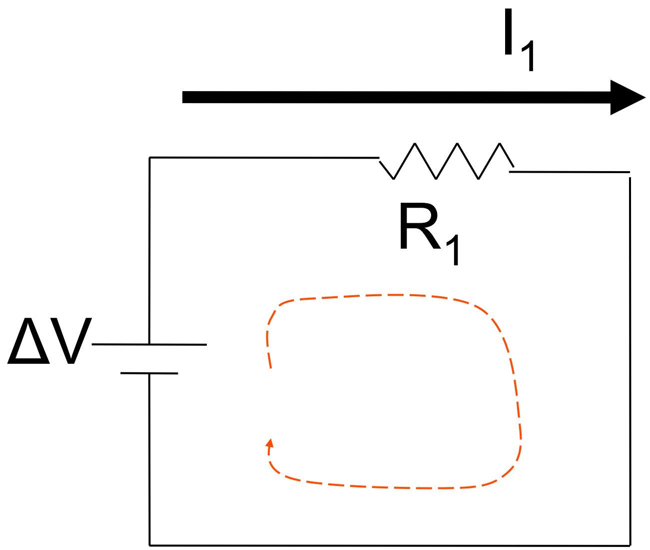


$$I_1 = I_2 + I_3$$

This comes from 'conservation of charge'

#2. Loop rule

"The sum of voltage differences in going around a closed current loop is equal to zero"



$$\sum_{loop} \Delta V_i = 0$$

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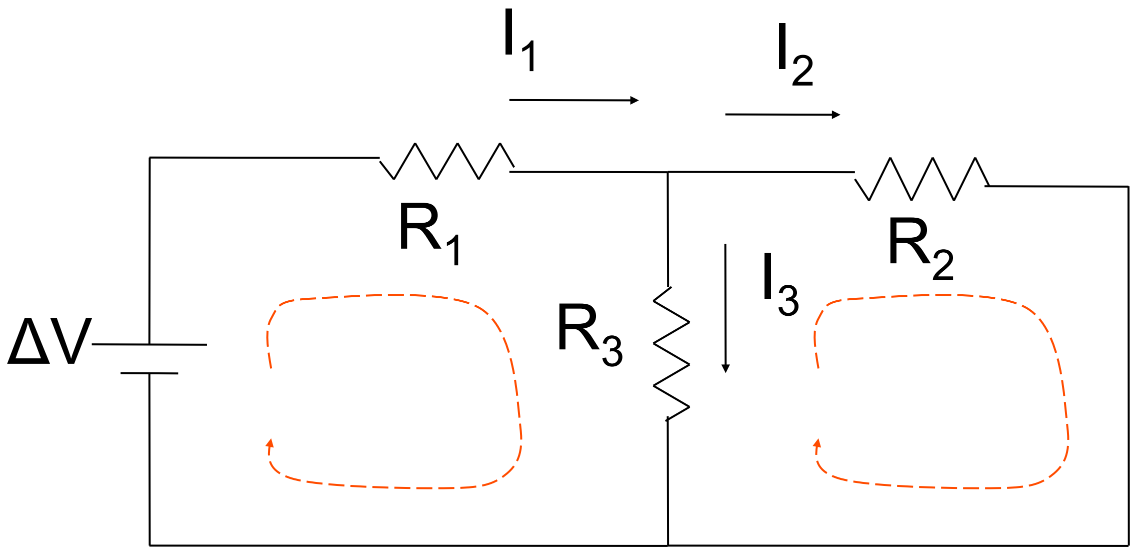
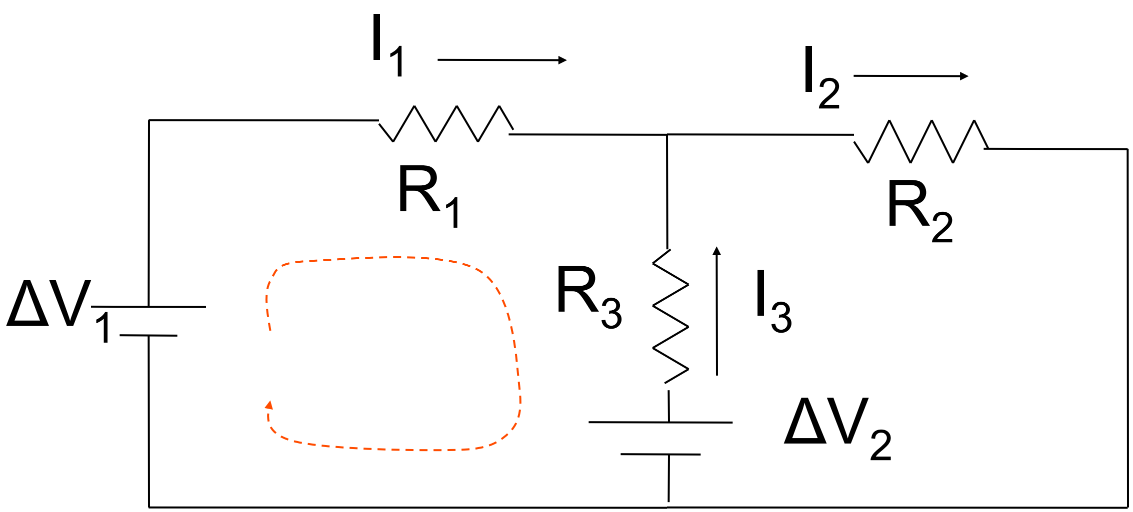


$$\sum_{loop} \Delta V_i = 0$$

Voltage changes in traversing the loop

Choose a current direction

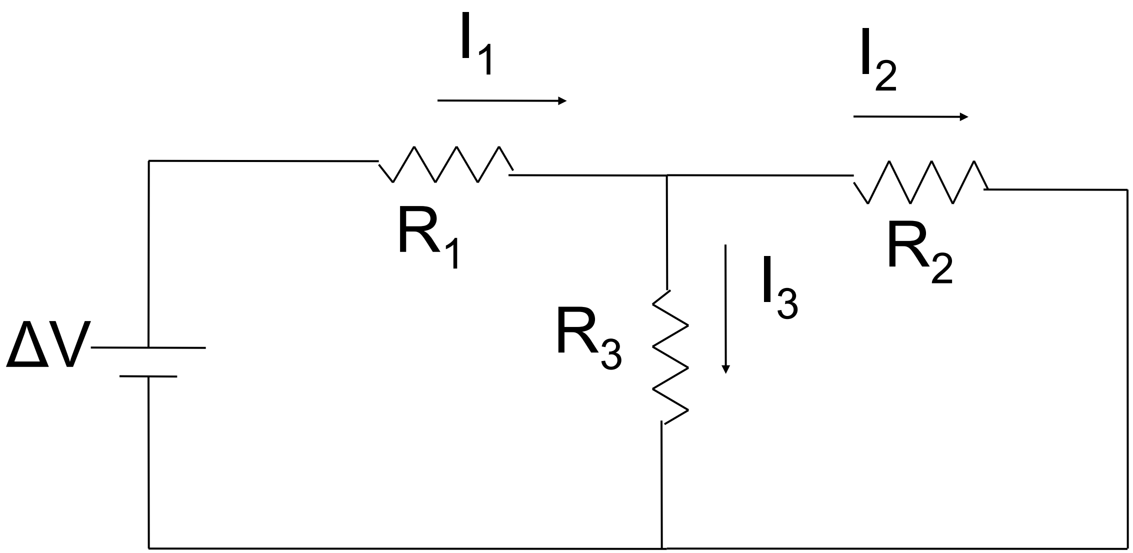
-IR, current in traversal direction
+IR current in opposite direction
+ΔV voltage increases along traversal direction
-ΔV voltage decreases along traversal direction



$$\Delta V_1 - I_1R_1 + I_3R_3 - \Delta V_2 = 0$$

If I is negative when you solve the equations, the current flows in the opposite direction than you chose.

Not all loop equations are independent



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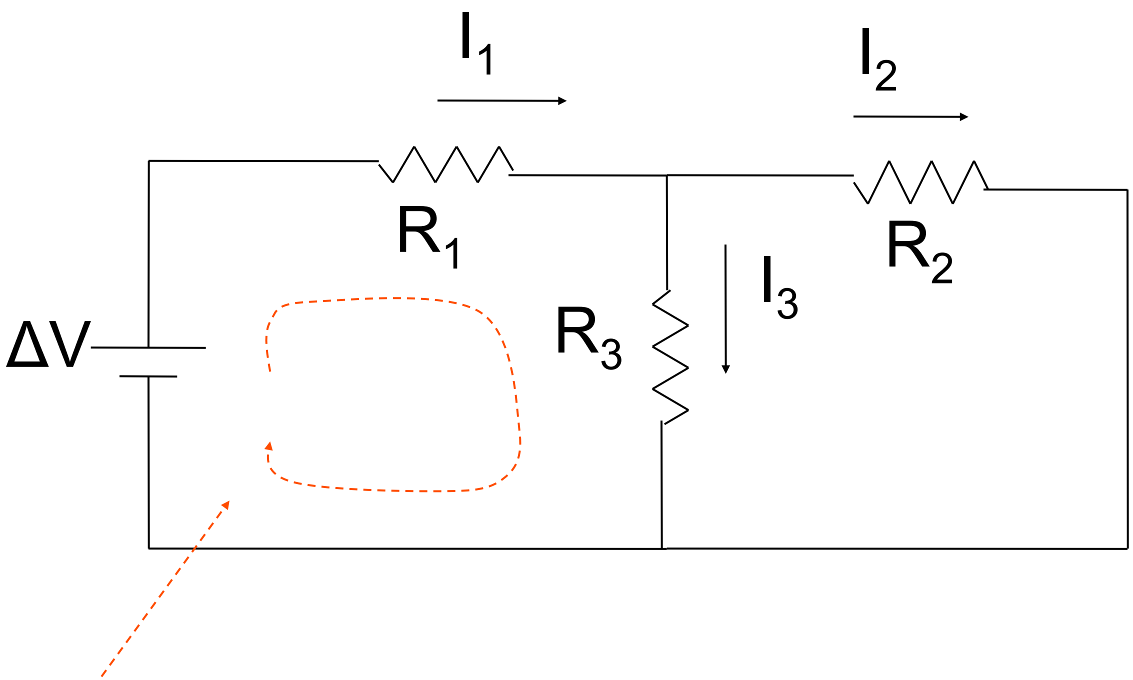

$$\Delta V - I_1 R_1 - I_3 R_3 = 0$$

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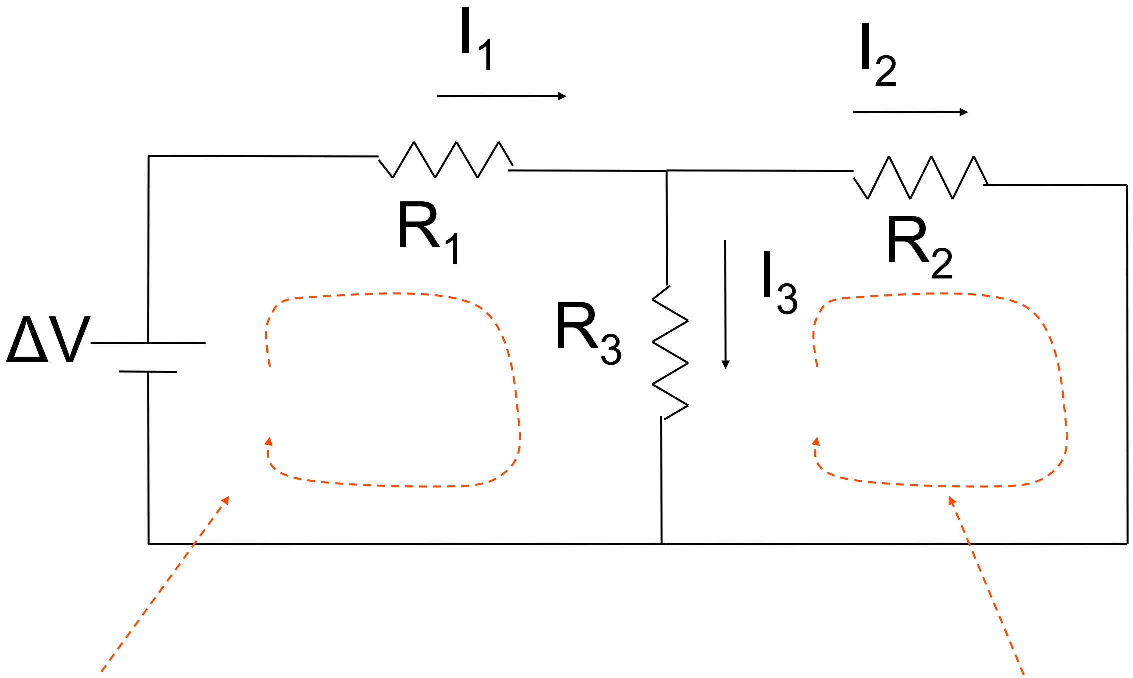
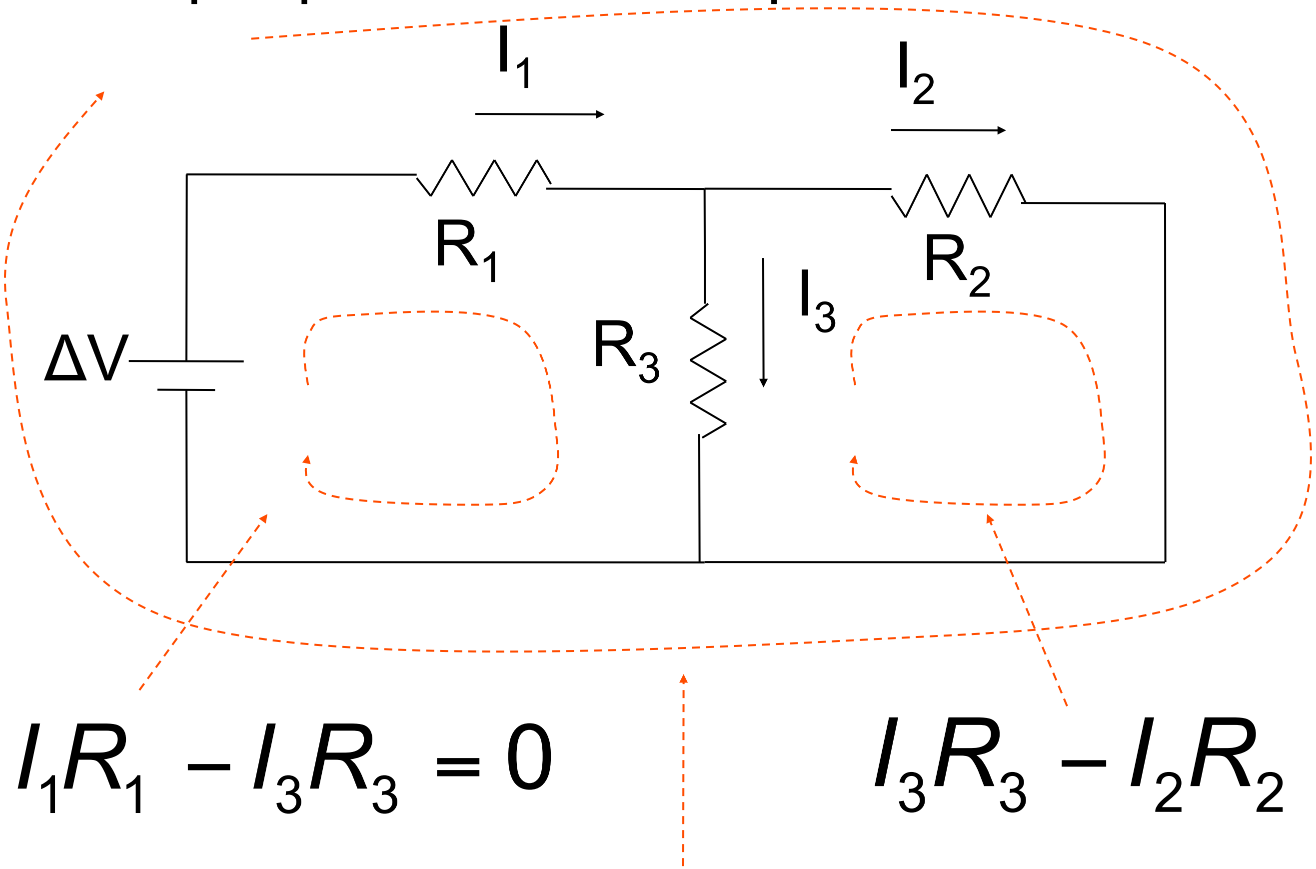


$$\Delta V - I_1R_1 - I_3R_3 = 0$$

$$I_3R_3 - I_2R_2 = 0$$

only 2 of these equations are independent

Not all loop equations are independent



$$\Delta V - I_1 R_1 - I_3 R_3 = 0$$

$$I_3 R_3 - I_2 R_2 = 0$$

$$\Delta V - I_1 R_1 - I_2 R_2 = 0$$

only 2 of these equations are independent

Using Kirchoff's rules

(1) Write the equations for the junction rule.

(2) Write the equations for the loop rule. Choose a direction for currents. If the current is negative then it flows in the opposite direction. Use as many equations as necessary to solve for all unknown quantities. (for n unknowns need n equations).

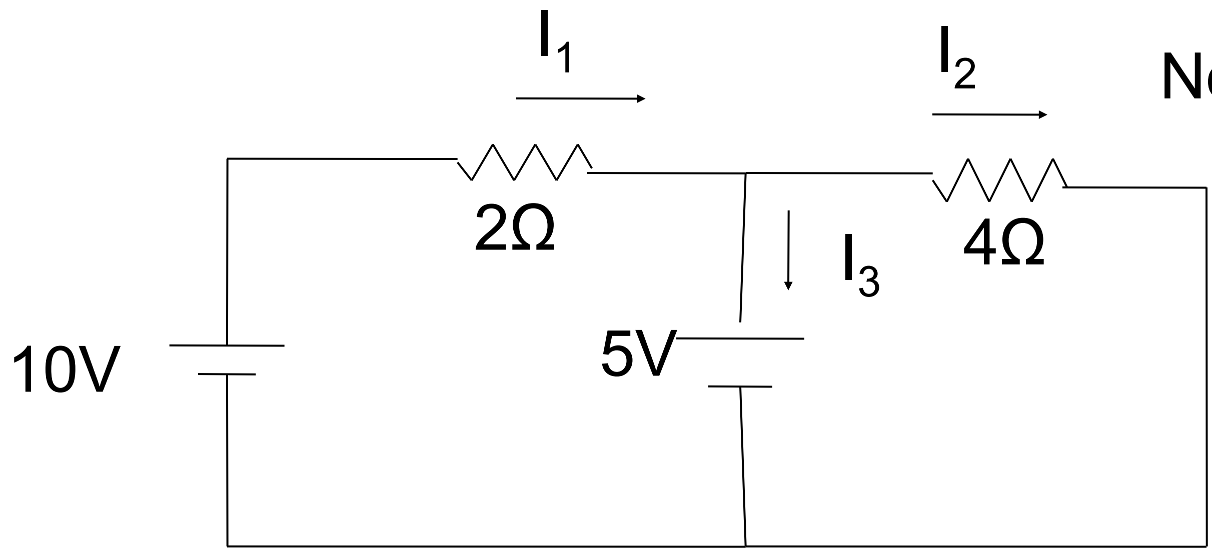
(3) Solve the set of equations for n unknown quantities.

No. equations needed=

Find I_1, I_2, I_3

no. Junction=

No. loop =



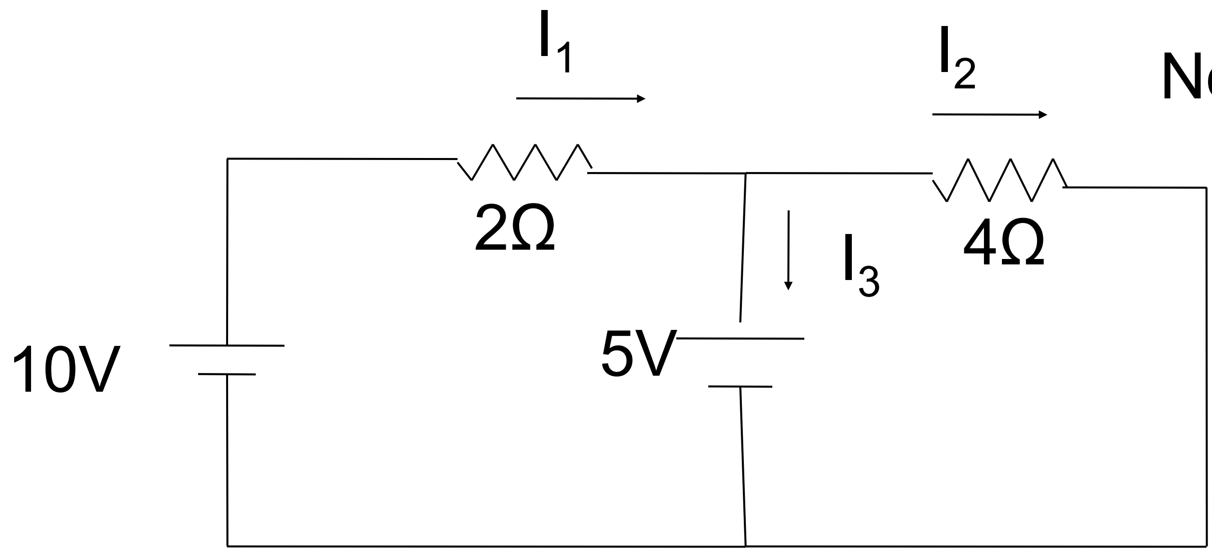
V=IR

No. equations needed= 3

Find I_1, I_2, I_3

no. Junction=

No. loop =



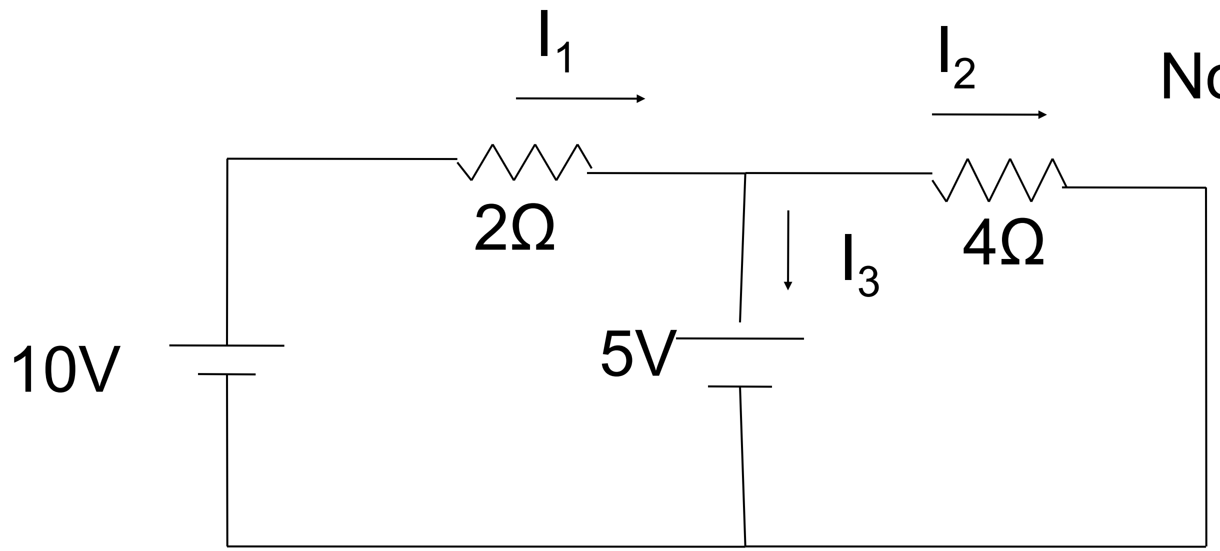
V=IR

Find I_1, I_2, I_3

No. equations needed= 3

no. Junction= 1

No. loop =



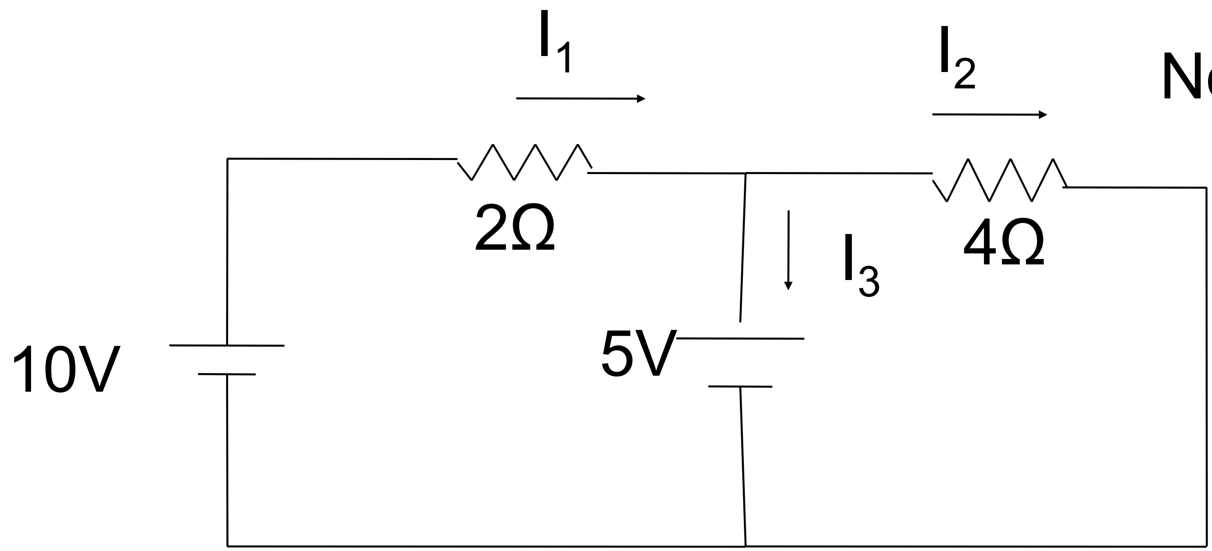
V=IR

No. equations needed= 3

no. Junction= 1

No. loop = 2

Find I_1, I_2, I_3



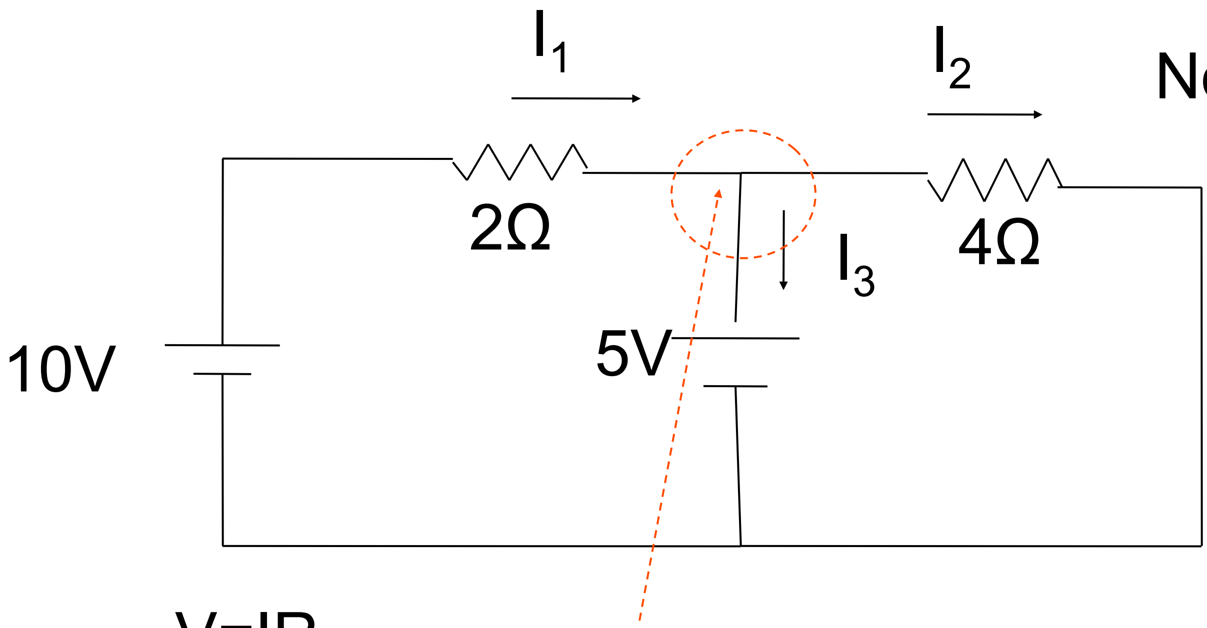
V=IR

Find I_1, I_2, I_3

No. equations needed= 3

no. Junction= 1

No. loop = 2



V=IR

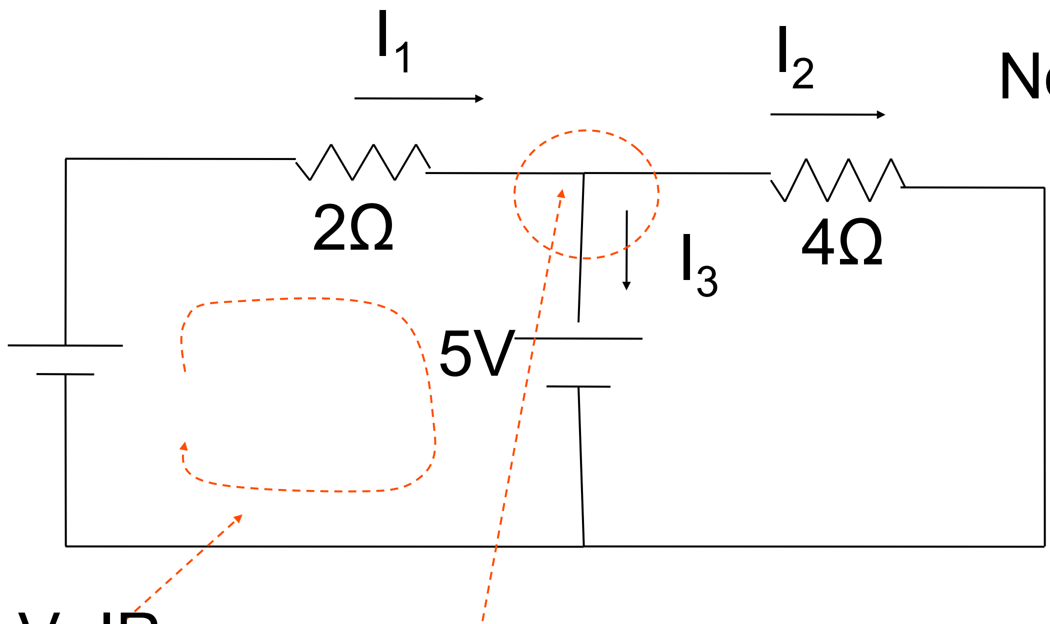
$$I_1 = I_2 + I_3$$

Find I_1, I_2, I_3

No. equations needed= 3

no. Junction= 1

No. loop = 2



V=IR

$$10 - 2I_1 - 5 = 0$$

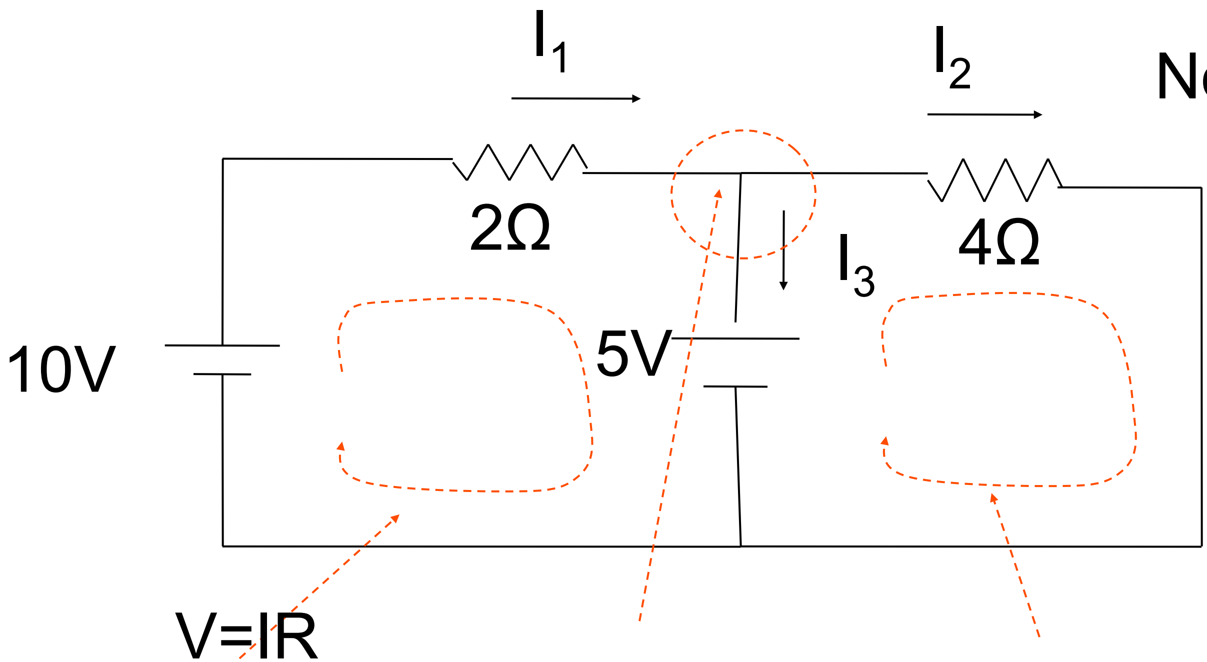
$$I_1 = I_2 + I_3$$

Find I_1, I_2, I_3

No. equations needed= 3

no. Junction= 1

No. loop = 2



V=IR

$$10 - 2I_1 - 5 = 0$$

$$I_1 = I_2 + I_3$$

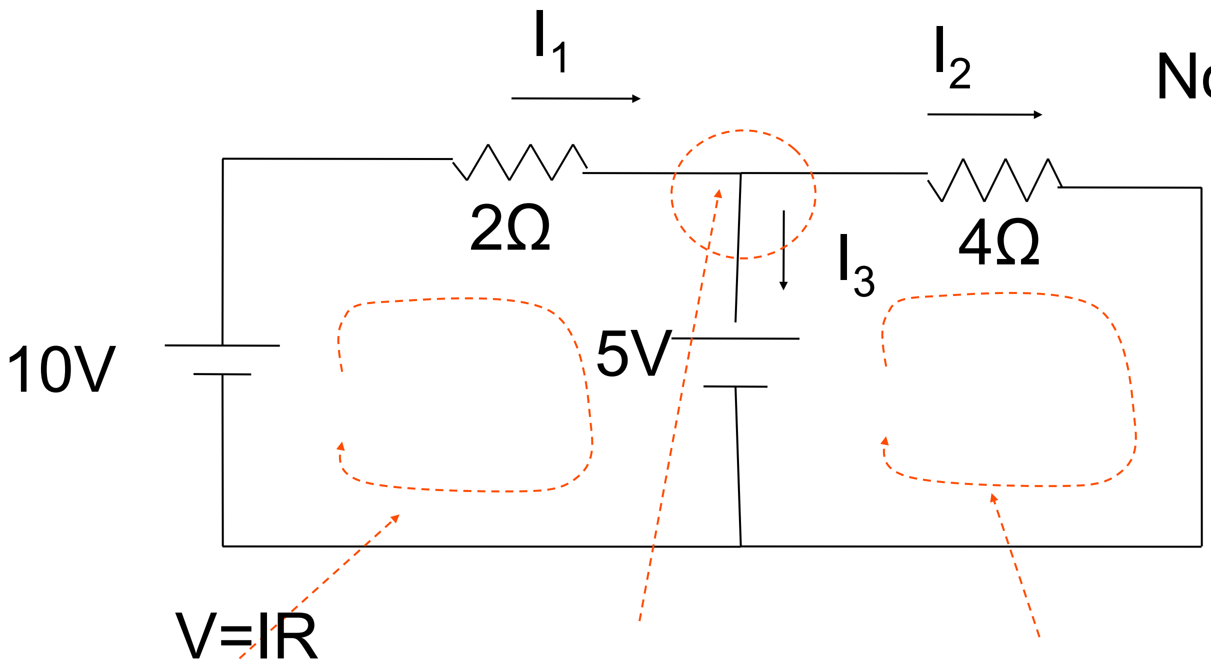
$$5 - 4I_2 = 0$$

Find I_1, I_2, I_3

No. equations needed= 3

no. Junction= 1

No. loop = 2



V=IR

$$10 - 2I_1 - 5 = 0$$

$$I_1 = I_2 + I_3$$

$$5 - 4I_2 = 0$$

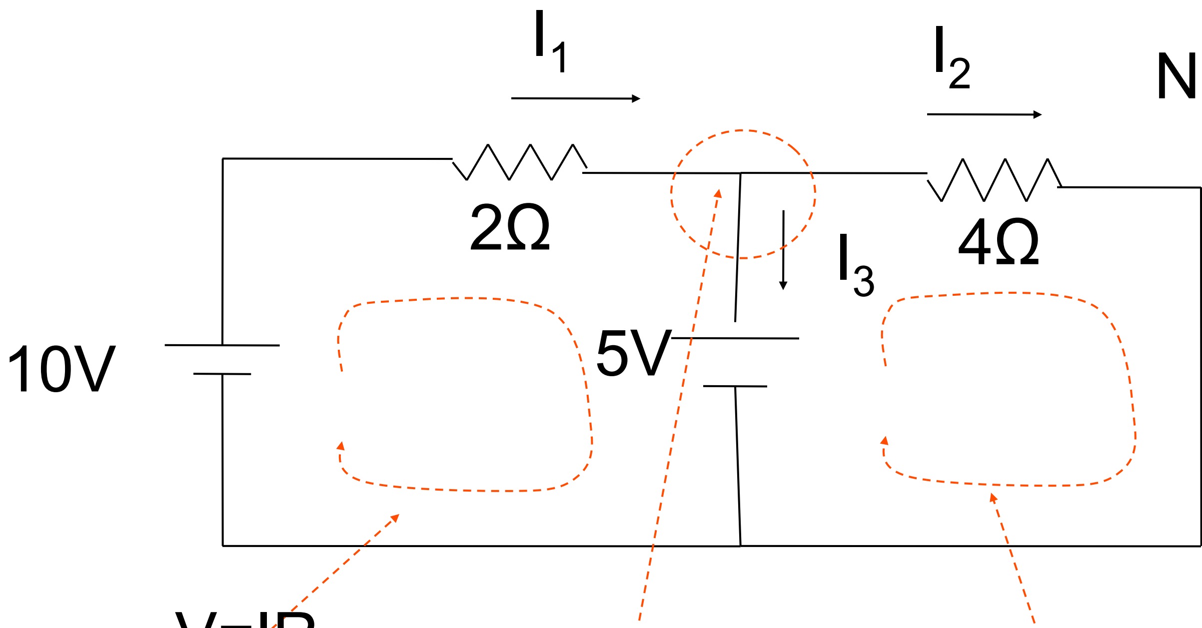
$$I_1 = \frac{10 - 5}{2} = 2.5A$$

No. equations needed= 3

Find I_1, I_2, I_3

no. Junction= 1

No. loop = 2



V=IR

$$10 - 2I_1 - 5 = 0$$

$$I_1 = I_2 + I_3$$

$$5 - 4I_2 = 0$$

$$I_1 = \frac{10-5}{2} = 2.5A$$

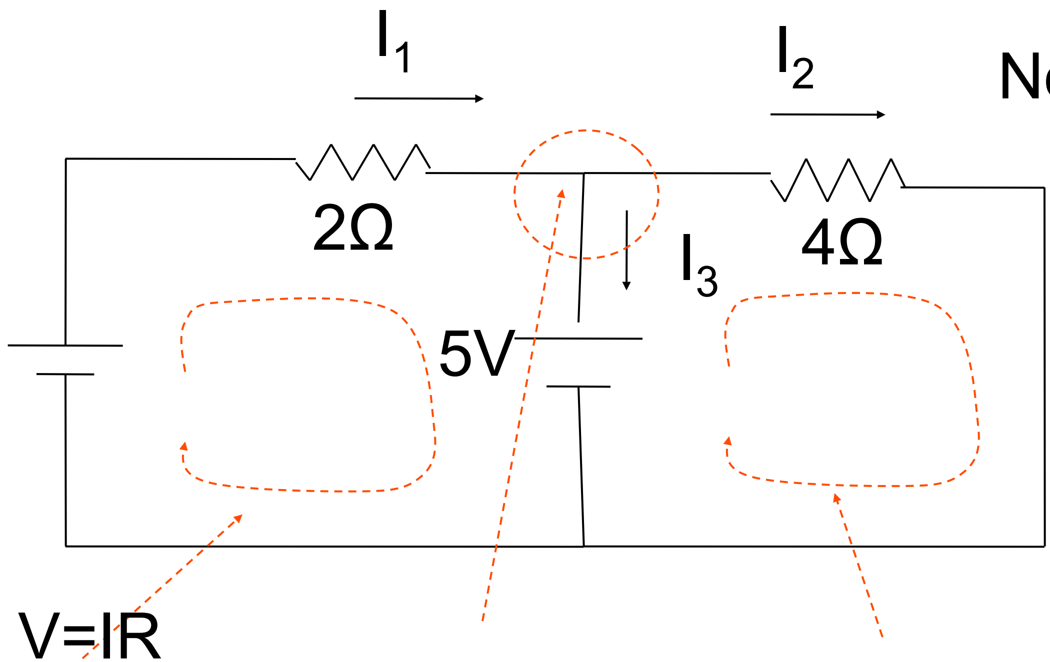
$$I_2 = \frac{5}{4} = 1.25A$$

Find I_1, I_2, I_3

No. equations needed= 3

no. Junction= 1

No. loop = 2



V=IR

$$10 - 2I_1 - 5 = 0$$

$$I_1 = \frac{10-5}{2} = 2.5A$$

$$I_1 = I_2 + I_3$$

$$5 - 4I_2 = 0$$

$$I_2 = \frac{5}{4} = 1.25A$$

$$I_3 = I_1 - I_2$$

$$I_3 = 2.5 - 1.25 = 1.25A$$

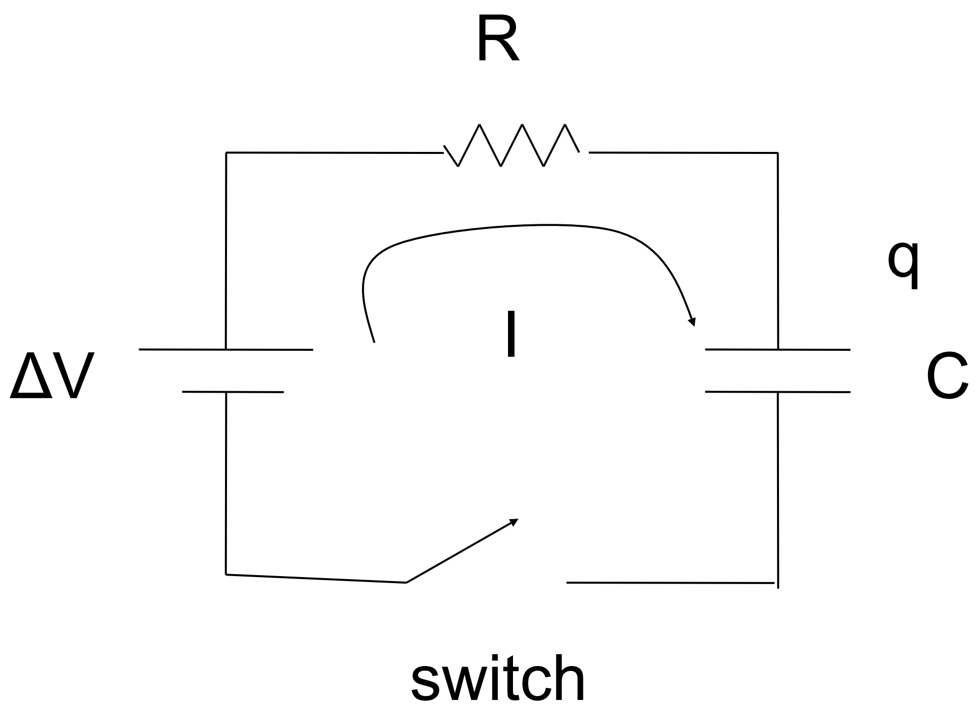
Chapter 18.5 RC circuit

Time dependent currents and voltages.

Applications. clocks, timing circuits, computers.

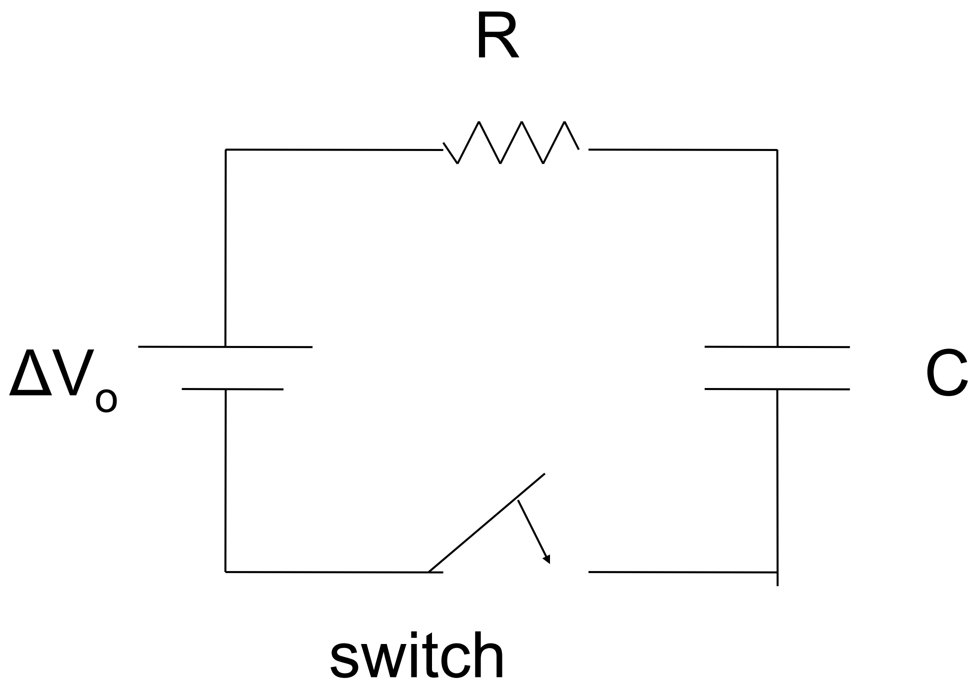
Time to charge and discharge of a capacitor

RC circuit



When the switch is closed how does the current and voltage change with time?

RC circuit

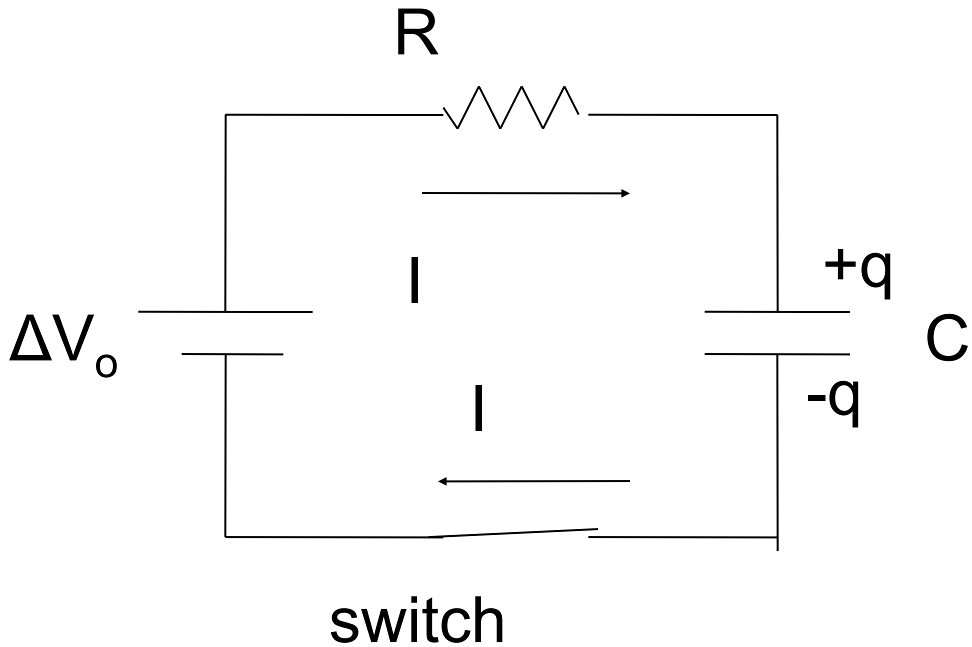


Switch off

Capacitor uncharged

$\Delta V_c=0$

Charging



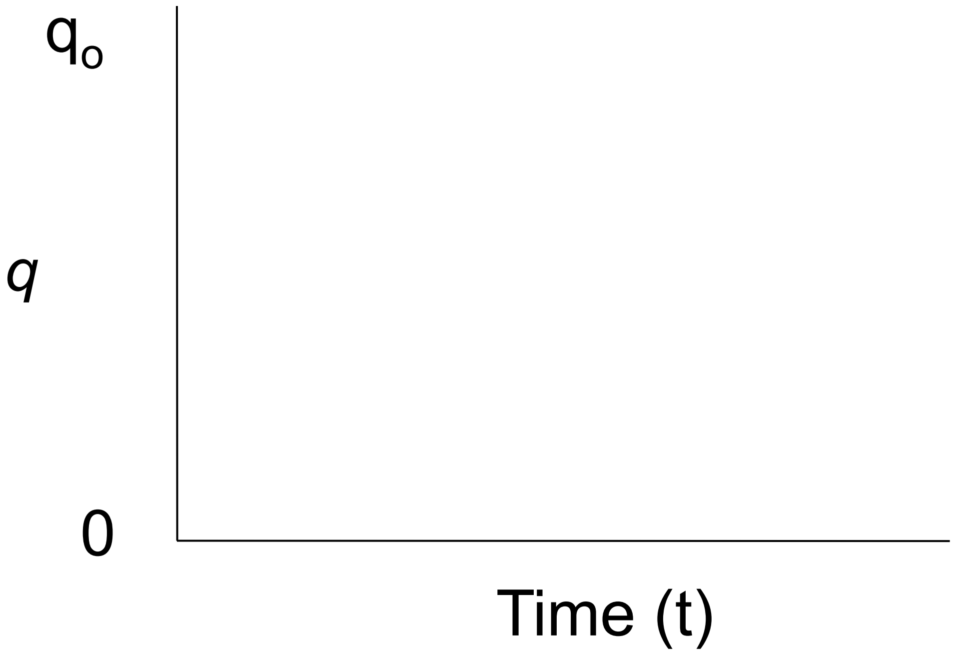
Switch on

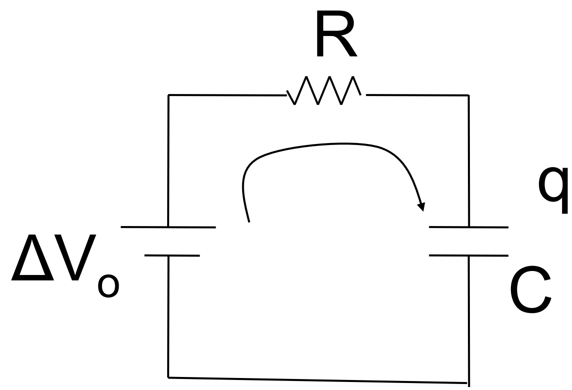
$$\Delta V_c = \frac{q}{C}$$

$$\Delta V_o - IR - \Delta V_c = 0$$

When the switch is initially closed the voltage on the capacitor is zero.
Charge is transferred to the capacitor at a rate I=dq/dt.
As the capacitor is charging the charge and voltage on the capacitor increases with time and the current decreases.

Charging Capacitor

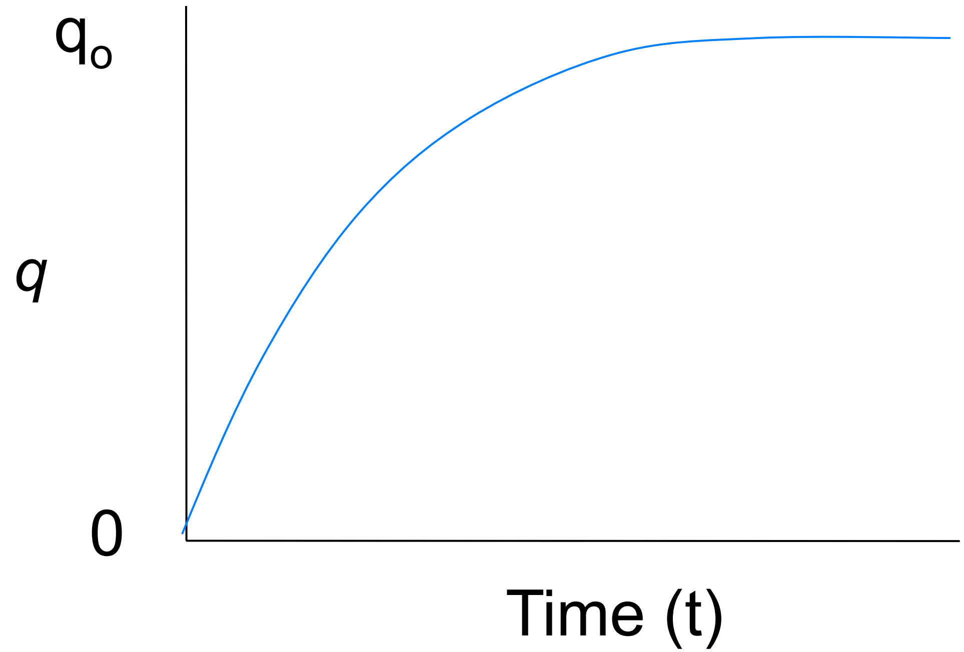


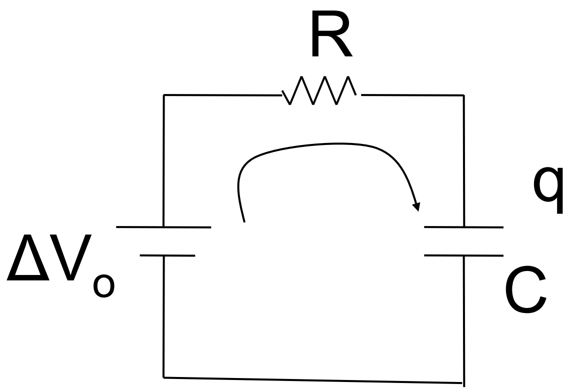


$$\Delta V_C = \frac{q}{C}$$

$$\Delta V_o = IR + \frac{q}{C}$$

Charging Capacitor

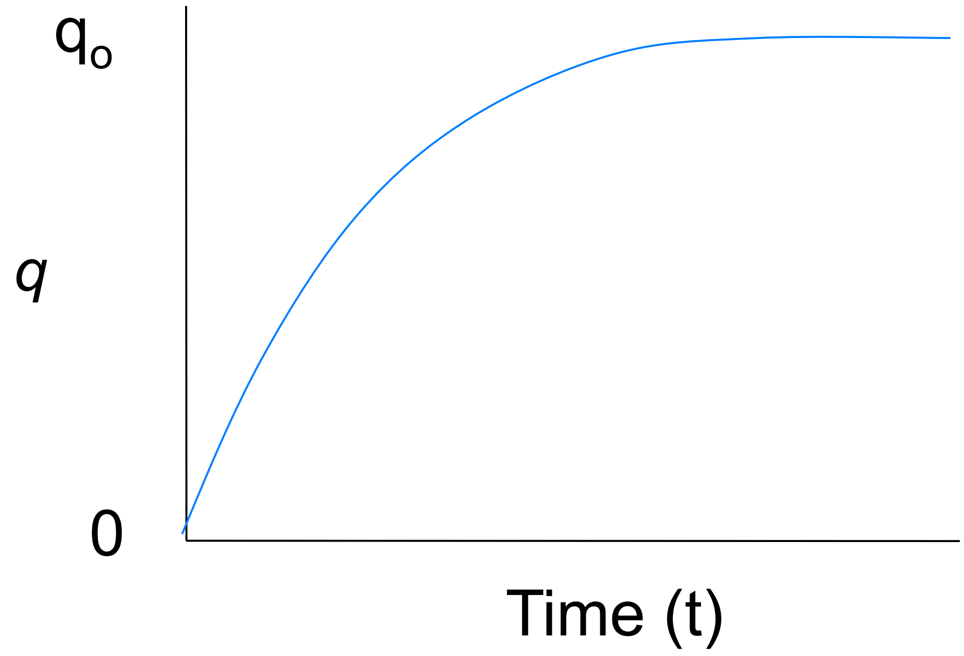


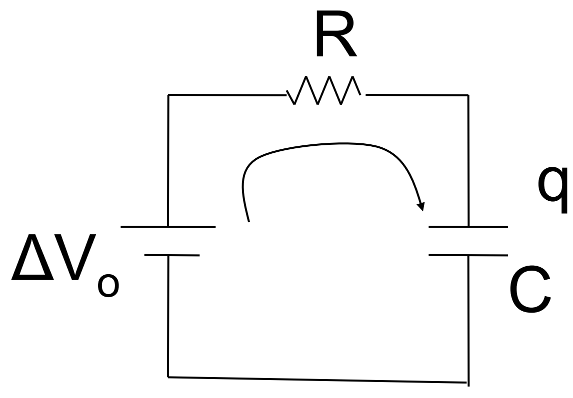


$$\Delta V_C = \frac{q}{C}$$

$$\Delta V_o = IR + \frac{q}{C}$$

Charging Capacitor





$$\Delta V_C = \frac{q}{C}$$

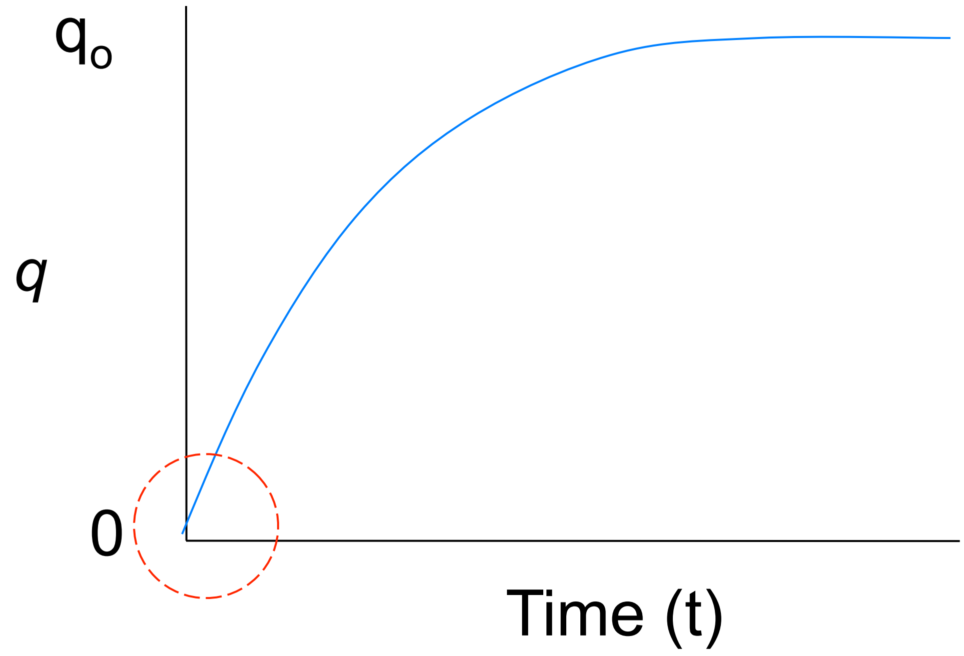
$$\Delta V_o = IR + \frac{q}{C}$$

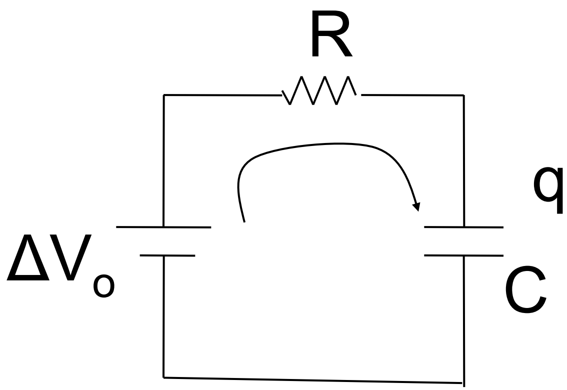
$q =$

$\Delta V_C =$

$I =$

Charging Capacitor





$\Delta V_C = \frac{q}{C}$

$$\Delta V_o = IR + \frac{q}{C}$$

short times

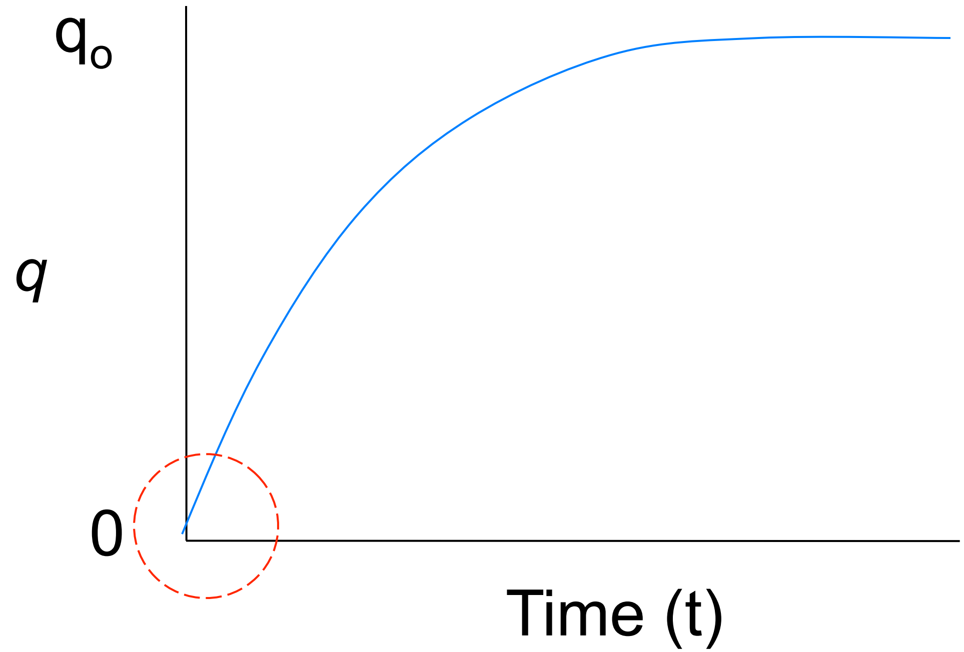
---

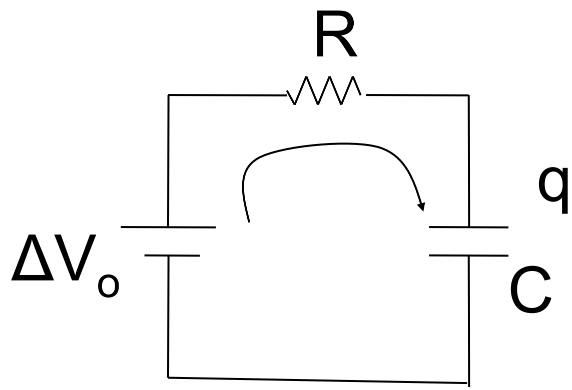
q =

$\Delta V_C =$

$I =$

Charging Capacitor





$$\Delta V_C = \frac{q}{C}$$

$$\Delta V_o = IR + \frac{q}{C}$$

short times

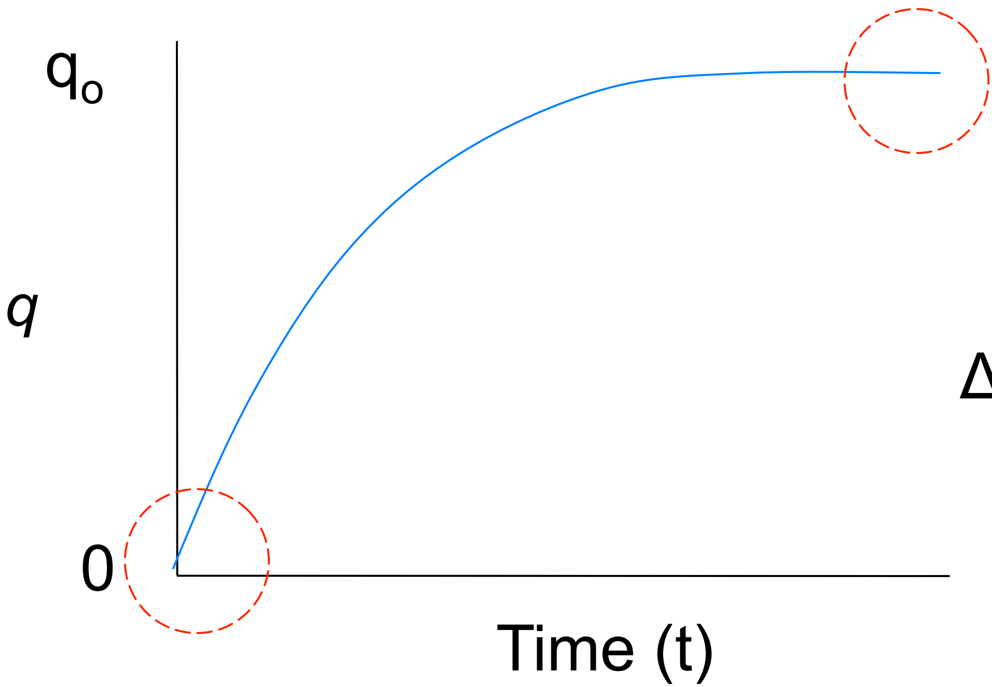
intermediate times

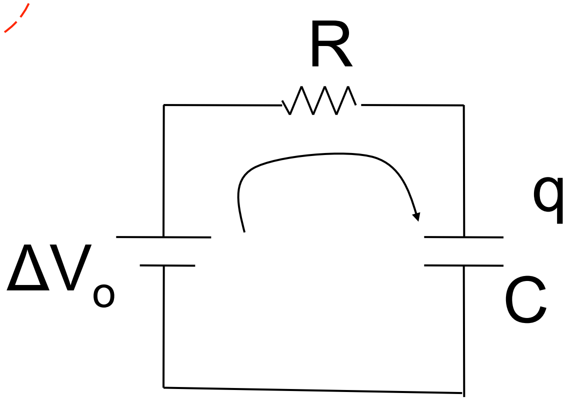
$q =$

$\Delta V_C =$

$I =$

Charging Capacitor





$$\Delta V_C = \frac{q}{C}$$

$$\Delta V_o = IR + \frac{q}{C}$$

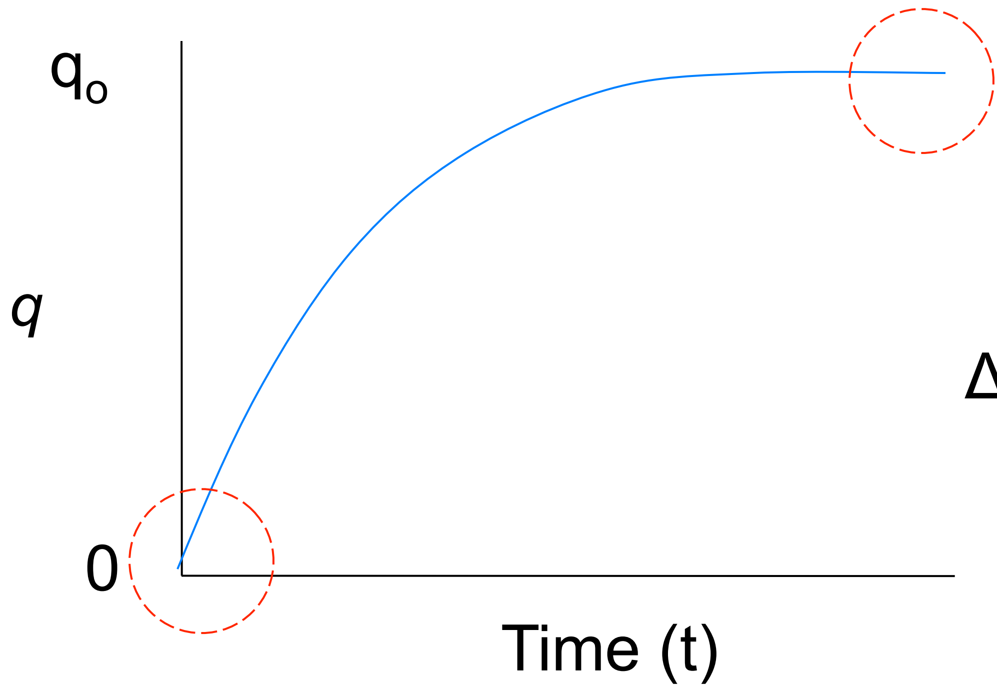
short times	intermediate times	long times

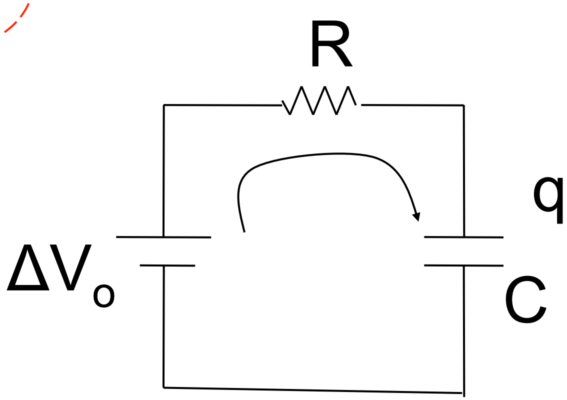
$q =$

$\Delta V_C =$

$I =$

Charging Capacitor





$$\Delta V_C = \frac{q}{C}$$

$$\Delta V_o = IR + \frac{q}{C}$$

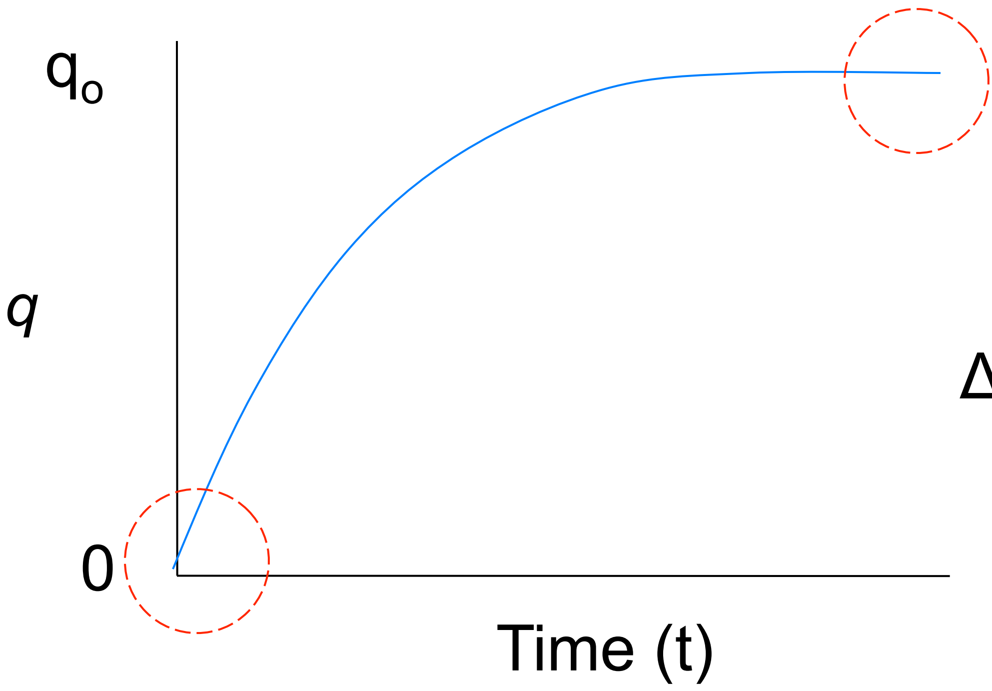
short times	intermediate times	long times

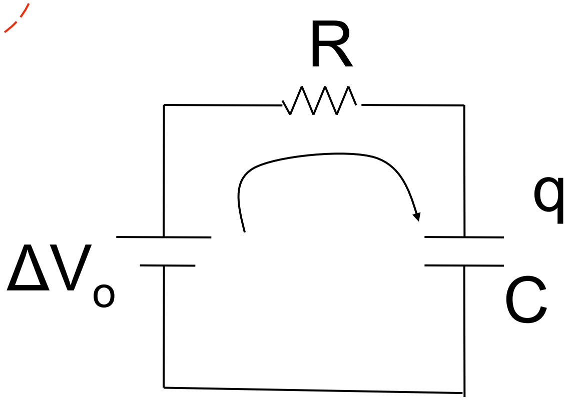
$q = \quad \sim 0$

$\Delta V_C =$

$I =$

Charging Capacitor





$\Delta V_C = \frac{q}{C}$

$$\Delta V_o = IR + \frac{q}{C}$$

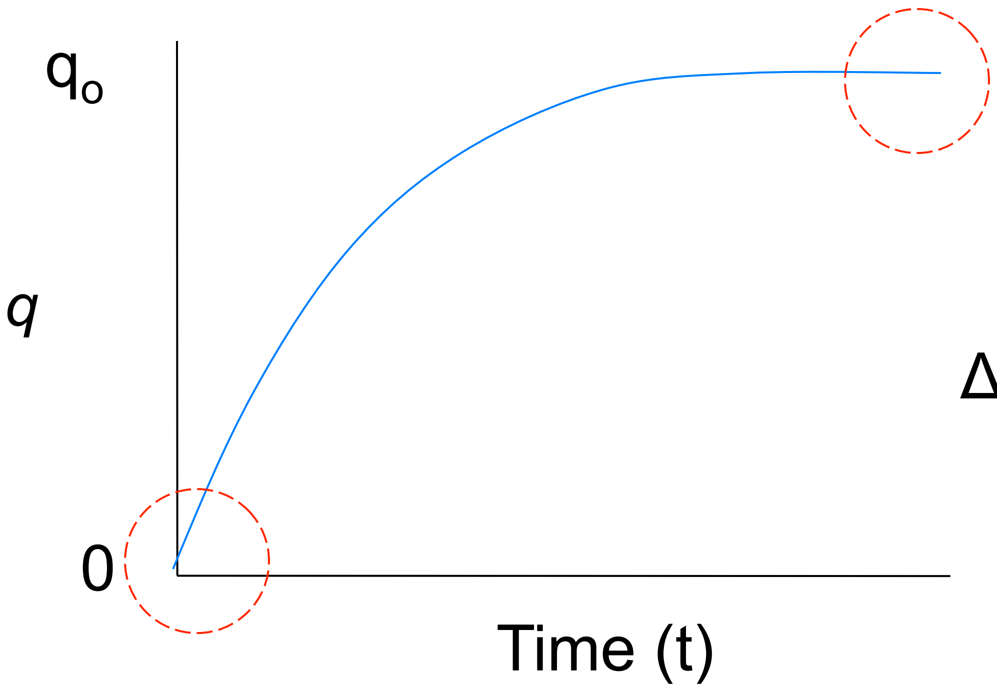
short times	intermediate times	long times

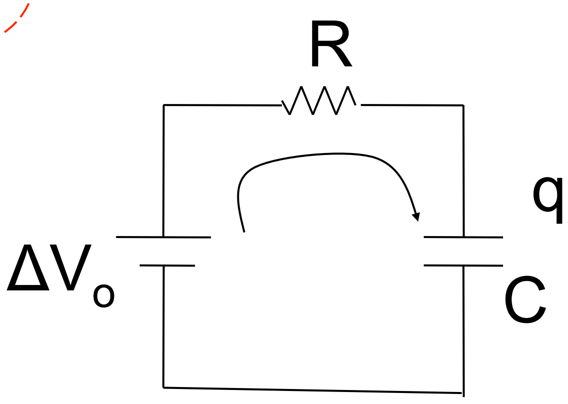
$q = \quad \sim 0$

$\Delta V_C = \quad \approx 0$

$I =$

Charging Capacitor





$$\Delta V_C = \frac{q}{C}$$

$$\Delta V_o = IR + \frac{q}{C}$$

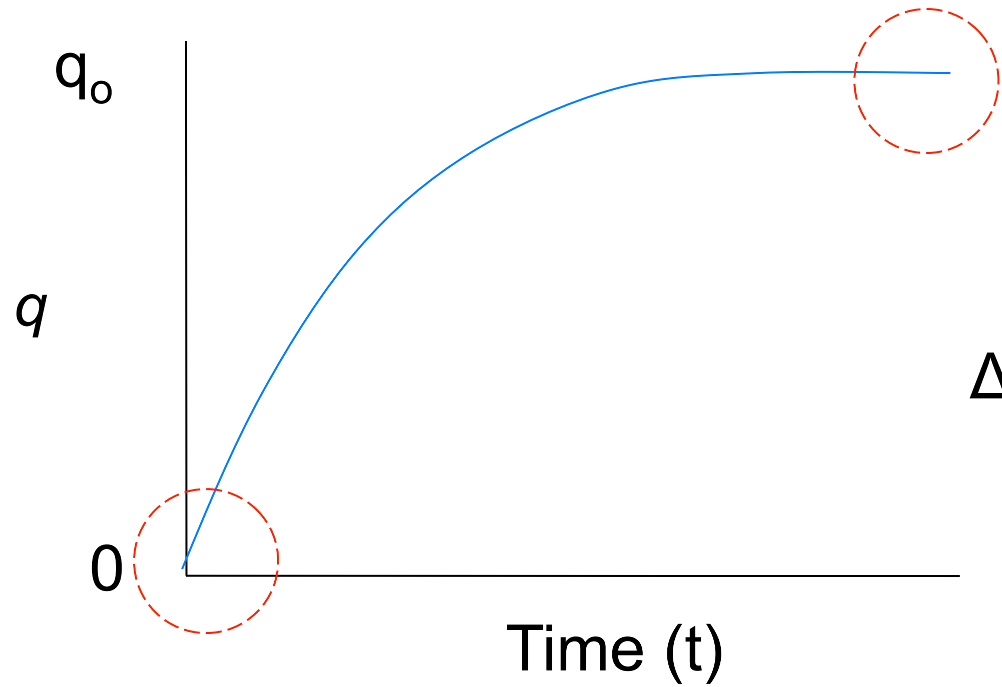
short times	intermediate times	long times

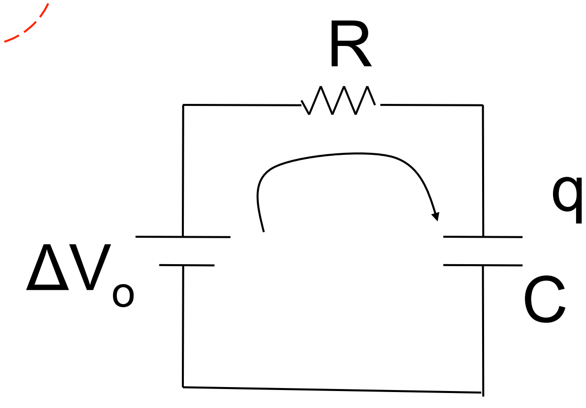
$q = \quad \sim 0$

$\Delta V_C = \quad \approx 0$

$I = \quad \approx \frac{\Delta V_o}{R}$

Charging Capacitor



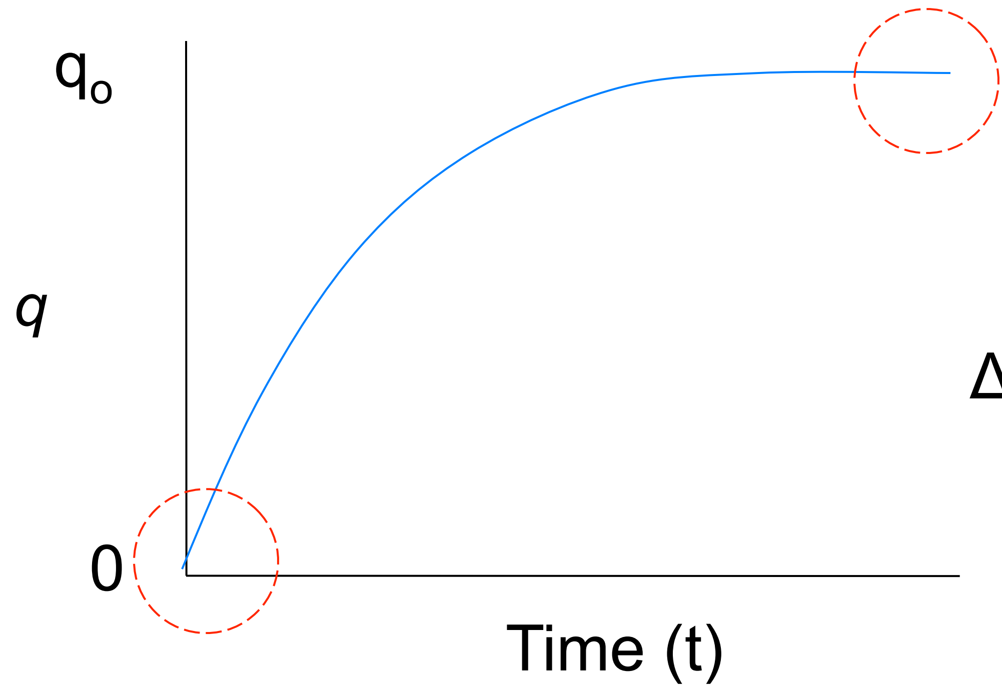


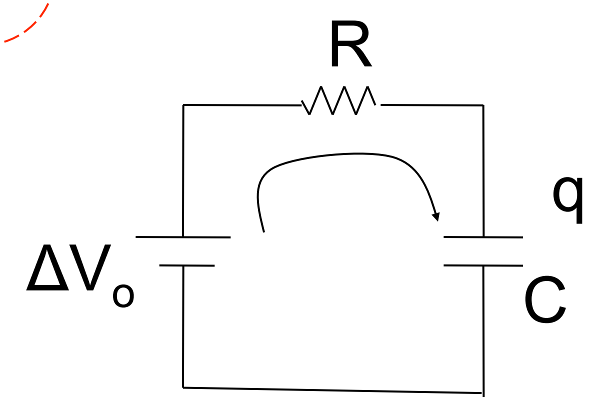
$$\Delta V_C = \frac{q}{C}$$

$$\Delta V_o = IR + \frac{q}{C}$$

	short times	intermediate times	long times
$q =$	~ 0		$q = q_o$
$\Delta V_C =$	≈ 0		
$I =$	$\approx \frac{\Delta V_o}{R}$		

Charging Capacitor



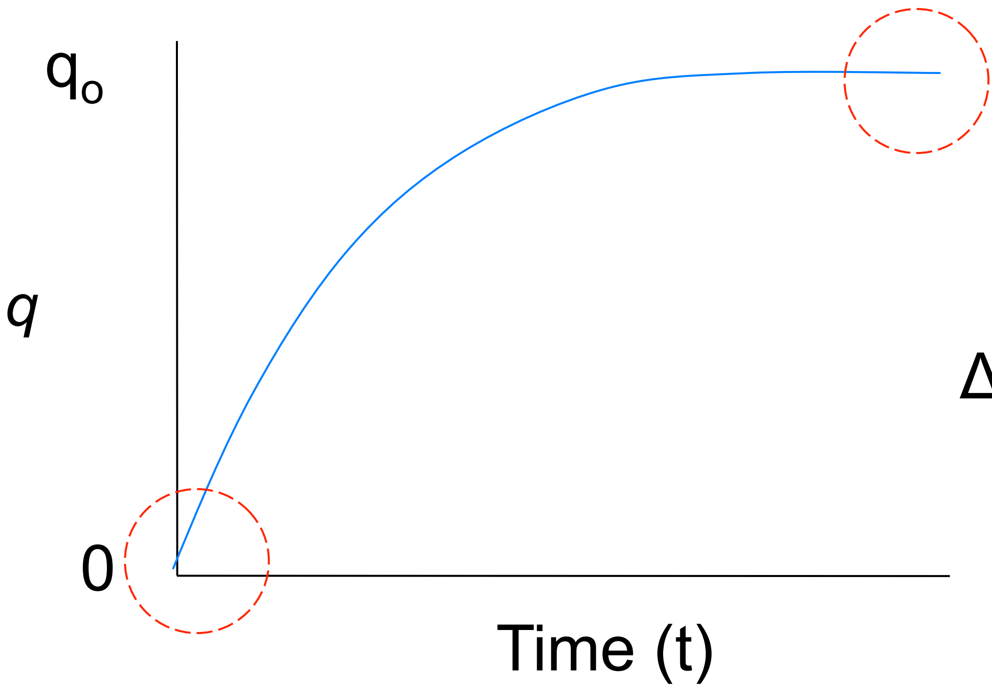


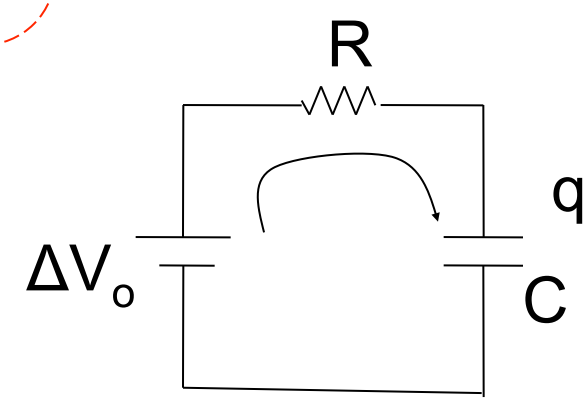
$$\Delta V_C = \frac{q}{C}$$

$$\Delta V_o = IR + \frac{q}{C}$$

short times	intermediate times	long times
$q = \sim 0$		$q = q_o$
$\Delta V_C = \approx 0$		$\Delta V_C = \Delta V_o$
$I = \approx \frac{\Delta V_o}{R}$		

Charging Capacitor



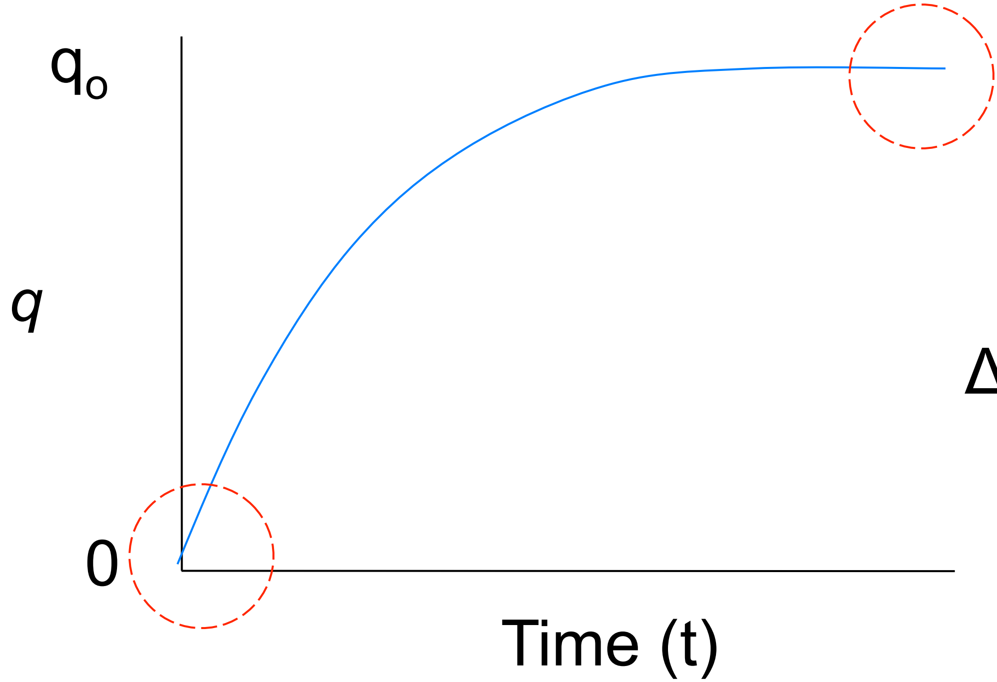


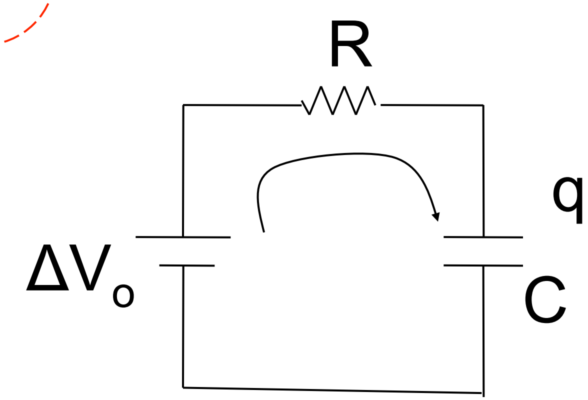
$$\Delta V_C = \frac{q}{C}$$

$$\Delta V_o = IR + \frac{q}{C}$$

short times	intermediate times	long times
$q = \sim 0$		$q = q_o$
$\Delta V_C = \approx 0$		$\Delta V_C = \Delta V_o$
$I = \approx \frac{\Delta V_o}{R}$		$I = 0$

Charging Capacitor



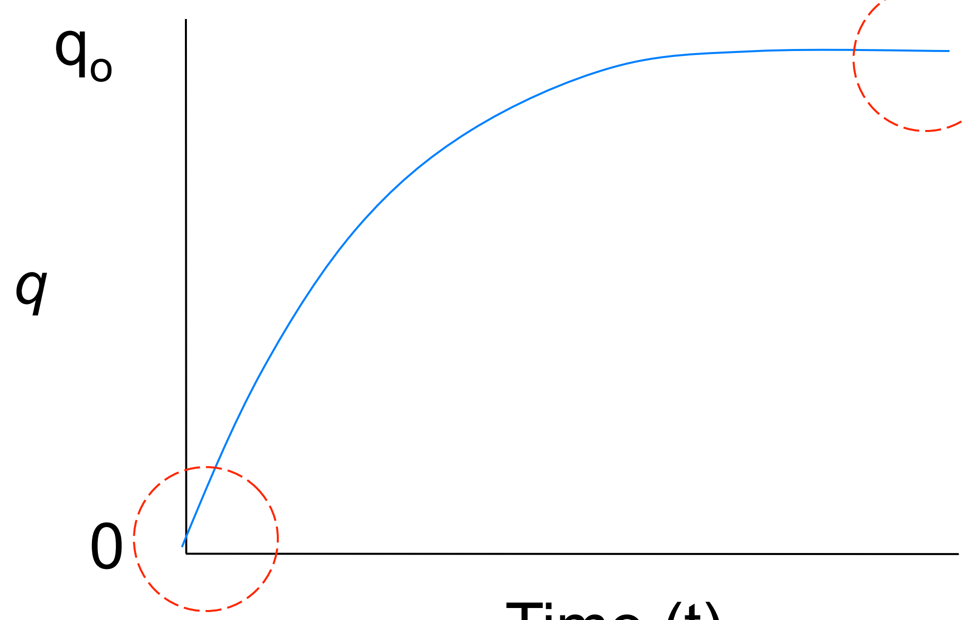


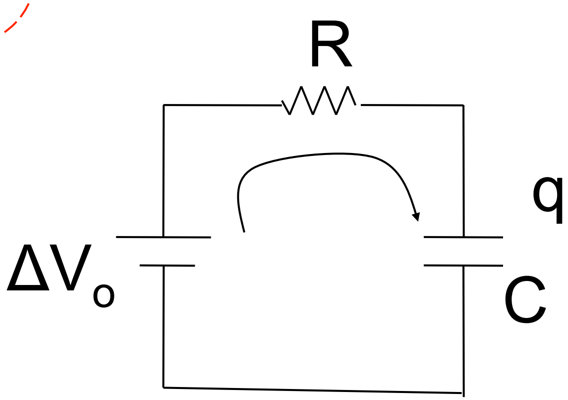
$$\Delta V_C = \frac{q}{C}$$

$$\Delta V_o = IR + \frac{q}{C}$$

short times	intermediate times	long times
$q = \;\sim 0$	$q = q_o(1 - e^{-\left(\frac{t}{\tau}\right)})$	$q = q_o$
$\Delta V_C = \;\approx 0$		$\Delta V_C = \Delta V_o$
$I = \;\approx \frac{\Delta V_o}{R}$		$I = 0$

Charging Capacitor



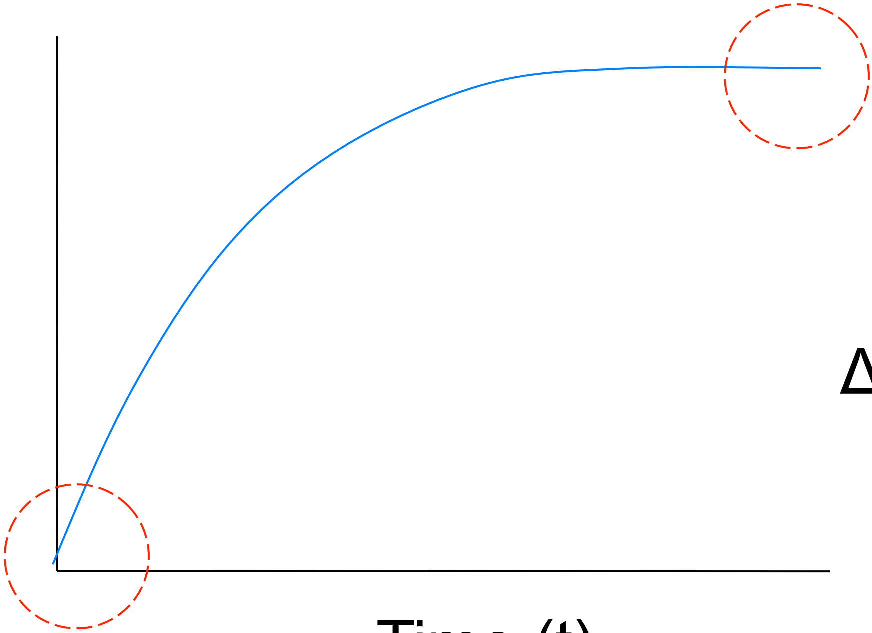


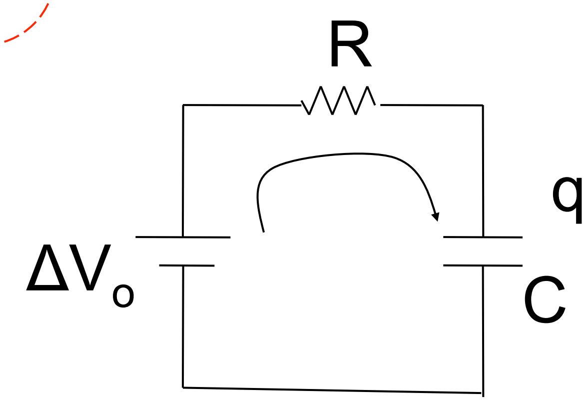
$$\Delta V_C = \frac{q}{C}$$

$$\Delta V_o = IR + \frac{q}{C}$$

short times	intermediate times	long times
$q = \sim 0$	$q = q_o(1 - e^{-\left(\frac{t}{\tau}\right)})$	$q = q_o$
$\Delta V_C = \approx 0$	$\Delta V_c = V_o(1 - e^{-\left(\frac{t}{\tau}\right)})$	$\Delta V_C = \Delta V_o$
$I = \approx \frac{\Delta V_o}{R}$		$I = 0$

Charging Capacitor



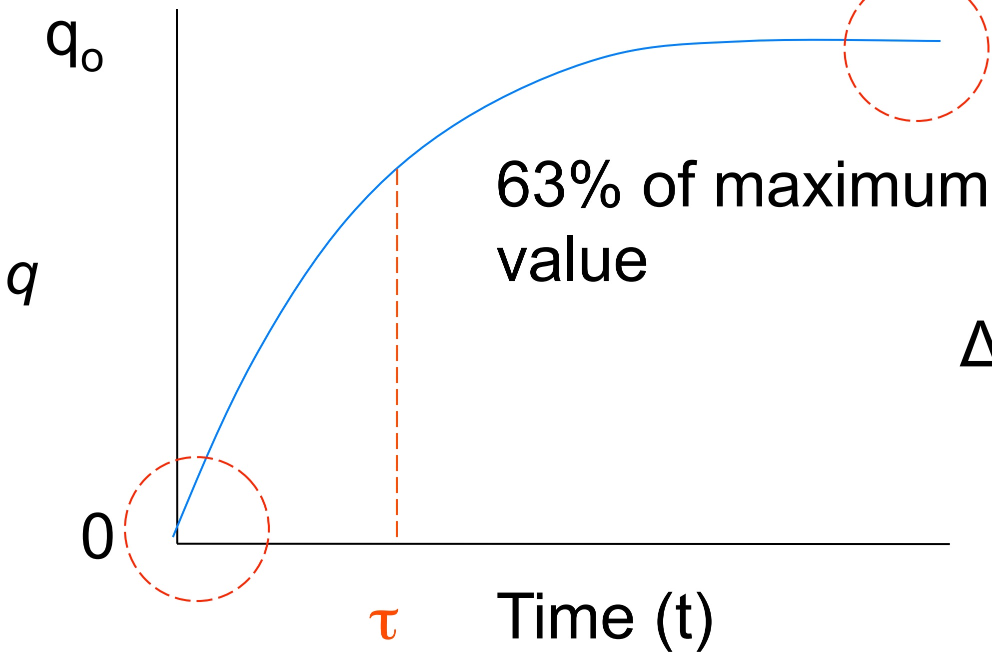


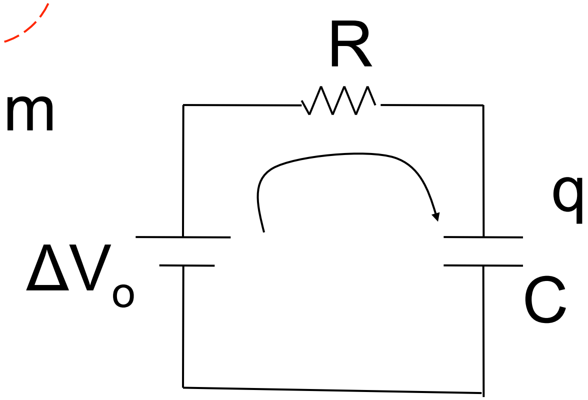
$$\Delta V_C = \frac{q}{C}$$

$$\Delta V_o = IR + \frac{q}{C}$$

short times	intermediate times	long times
$q = \sim 0$	$q = q_o(1 - e^{-\left(\frac{t}{\tau}\right)})$	$q = q_o$
$\Delta V_C = \approx 0$	$\Delta V_c = V_o(1 - e^{-\left(\frac{t}{\tau}\right)})$	$\Delta V_C = \Delta V_o$
$I = \approx \frac{\Delta V_o}{R}$	$I = \frac{\Delta V_o}{R} e^{-\left(\frac{t}{\tau}\right)}$	$I = 0$

Charging Capacitor





$$\Delta V_C = \frac{q}{C}$$

$$\Delta V_o = IR + \frac{q}{C}$$

short times	intermediate times	long times
$q = \ \sim 0$	$q = q_o(1 - e^{-\left(\frac{t}{\tau}\right)})$	$q = q_o$
$\Delta V_C = \ \approx 0$	$\Delta V_c = V_o(1 - e^{-\left(\frac{t}{\tau}\right)})$	$\Delta V_C = \Delta V_o$
$I = \ \approx \frac{\Delta V_o}{R}$	$I = \frac{\Delta V_o}{R} e^{-\left(\frac{t}{\tau}\right)}$	$I = 0$

$$\tau = RC$$

PHYSICS 1B – Fall 2009

Electricity
&
Magnetism

Professor Brian Keating
SERF Building. Room 333

UCSD UCSD

Time Constant

$$\tau = RC$$

Dimensional analysis

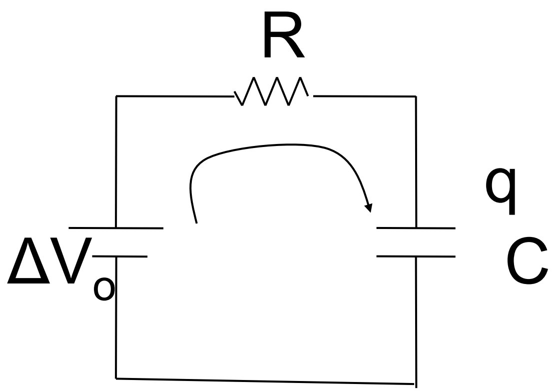
$$RC = \frac{V}{I}\frac{q}{V} = \frac{q}{I} = \frac{q}{q/t} = t$$

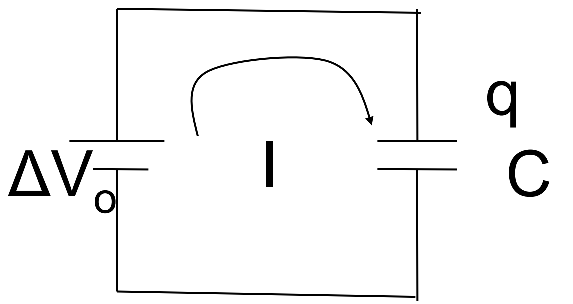
RC has units of time

Time required to charge the capacitor

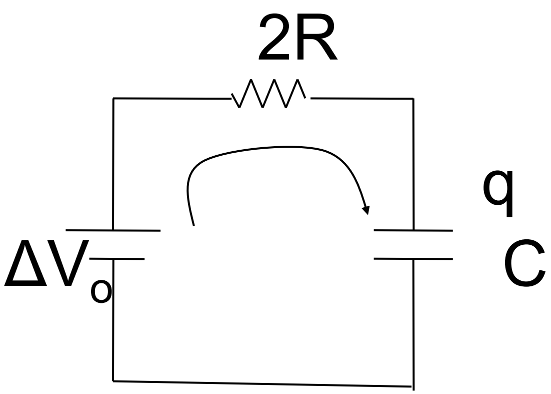
- increases with R – lower current flow
- Increases with C - more charge on capacitor

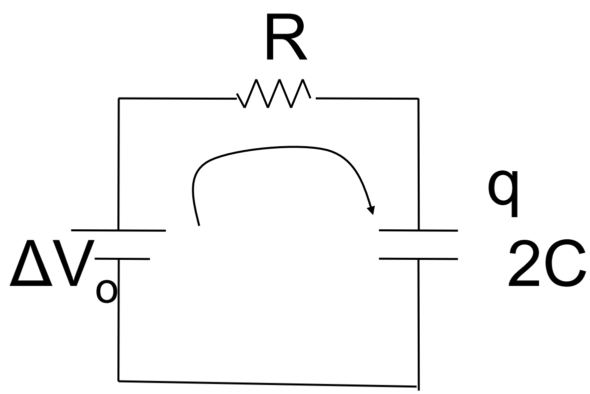
How does the time to charge the capacitor depend on R and C



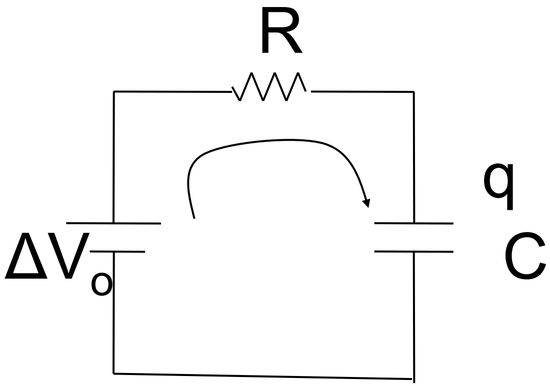


Charging time τ_o

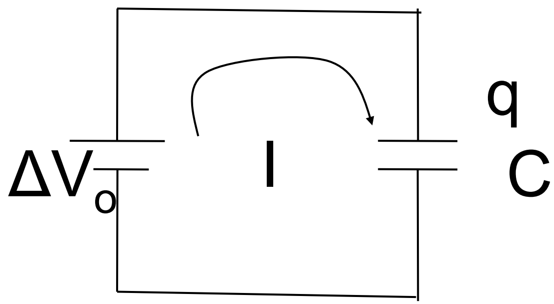




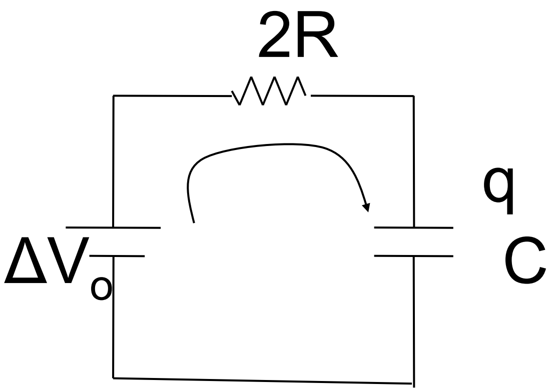
How does the time to charge the capacitor depend on R and C

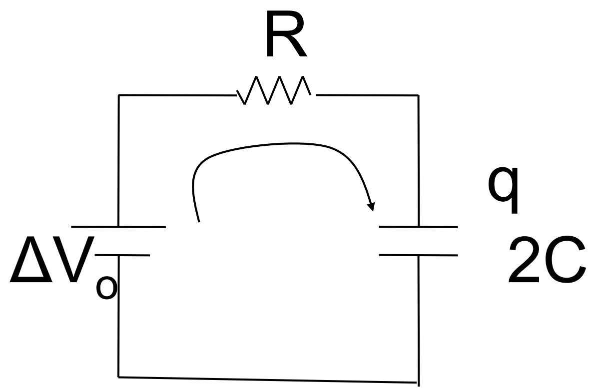


Charging time τ_o



shorter than τ_o because the current is larger





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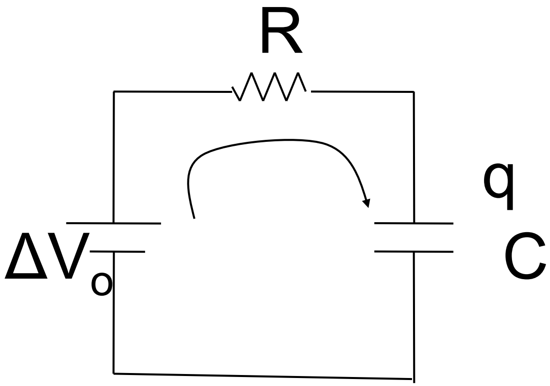

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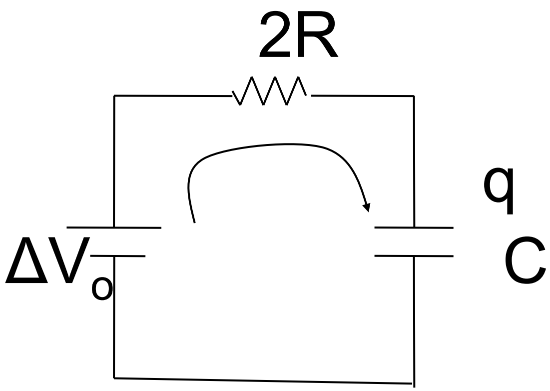
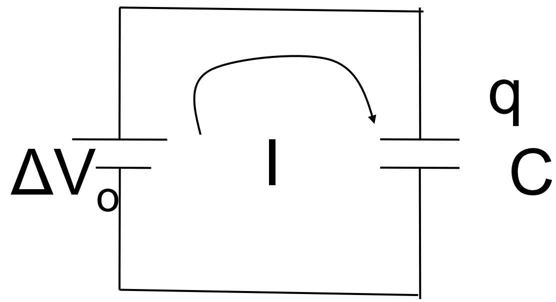


longer than τ_o
the current is smaller



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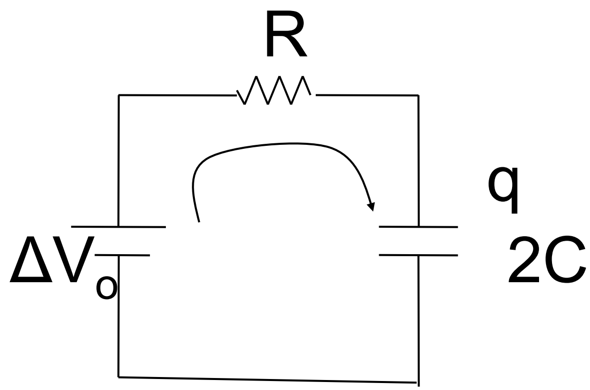
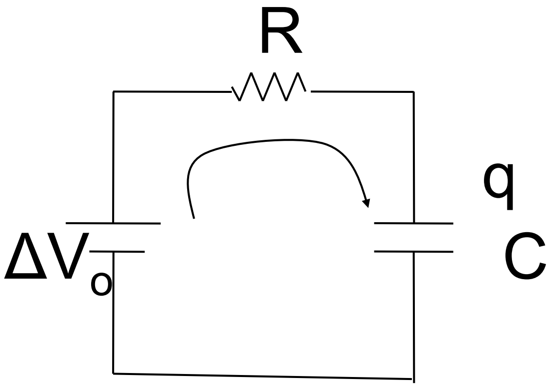
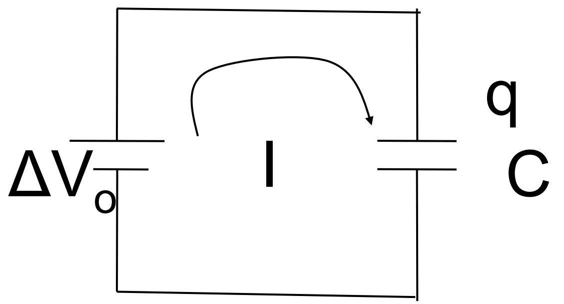


How does the time to charge the capacitor depend on R and C



Charging time τ_o



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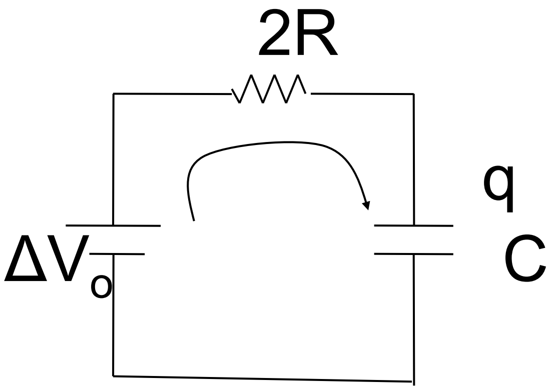
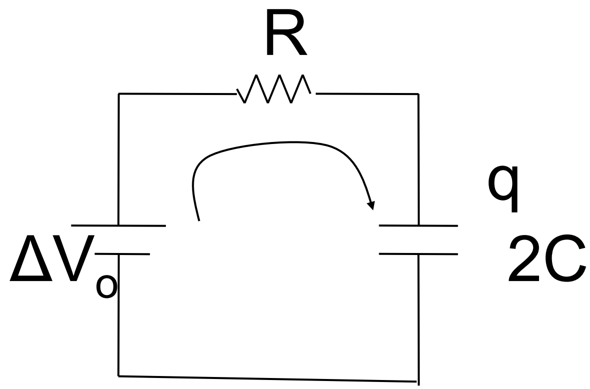
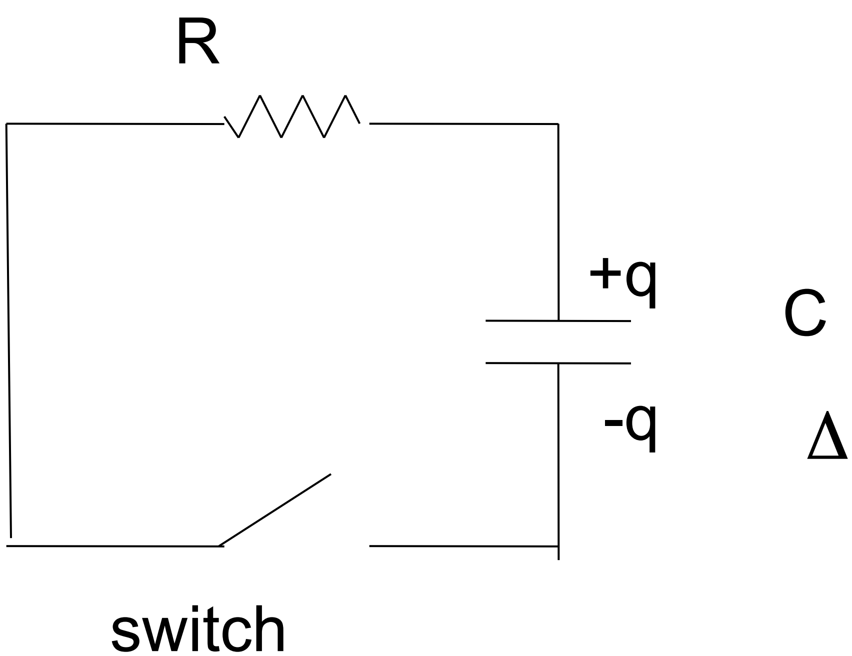


longer than τ_o
the current is smaller



longer than τ_o
more charge is transferred

Discharging



Switch off

Capacitor charged

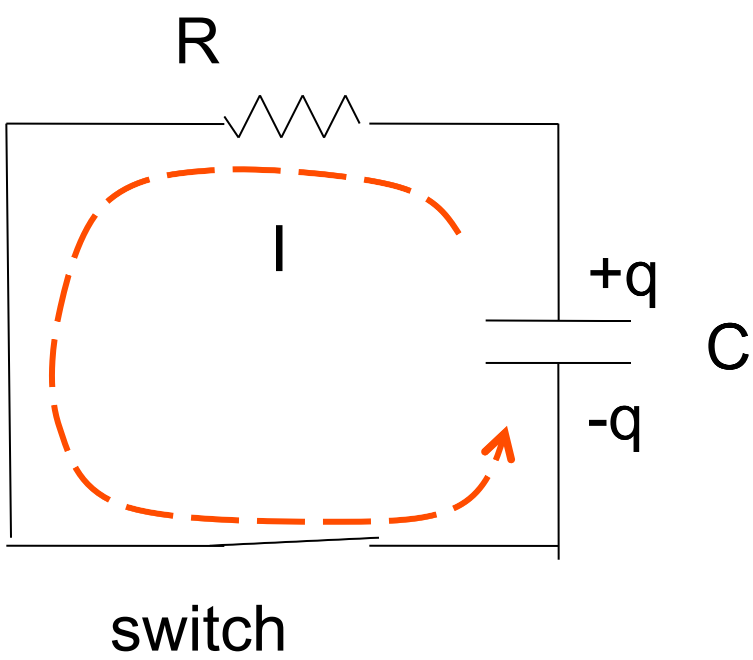
$$\Delta V_c = \frac{q}{C}$$

When the switch is closed to discharge the capacitor the capacitor has a maximum charge of q_o and maximum voltage V_o.

As the capacitor discharges the charge and voltage decrease with time.

The current will also decrease with time.

Discharge



Switch on

Current flows

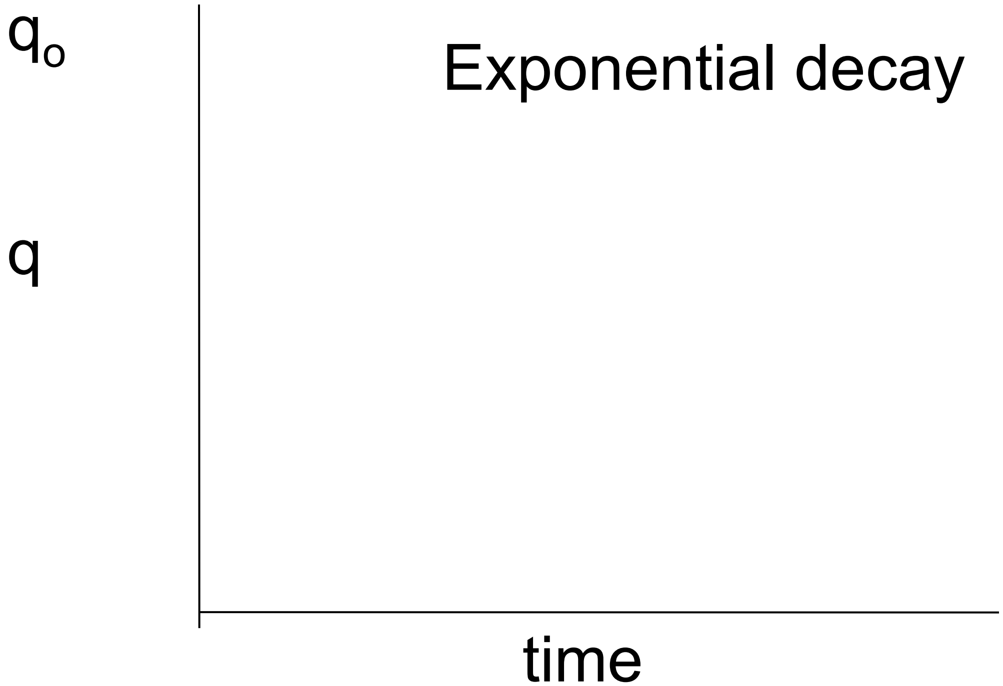
$$\Delta V_R = IR = \Delta V_c = \frac{q}{C}$$

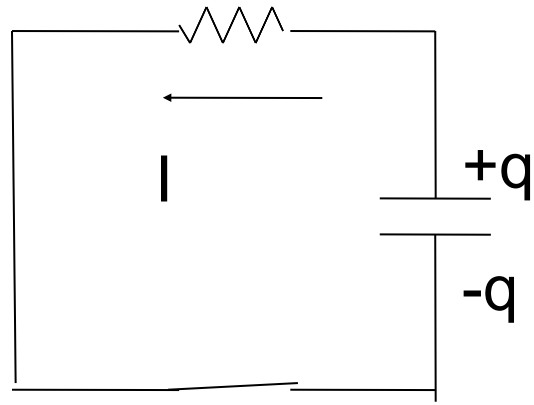
$$I = -\frac{\Delta q}{\Delta t} = \frac{q}{RC}$$

$$q = q_o e^{-\left(\frac{t}{\tau}\right)}$$

The charge decays exponentially with time

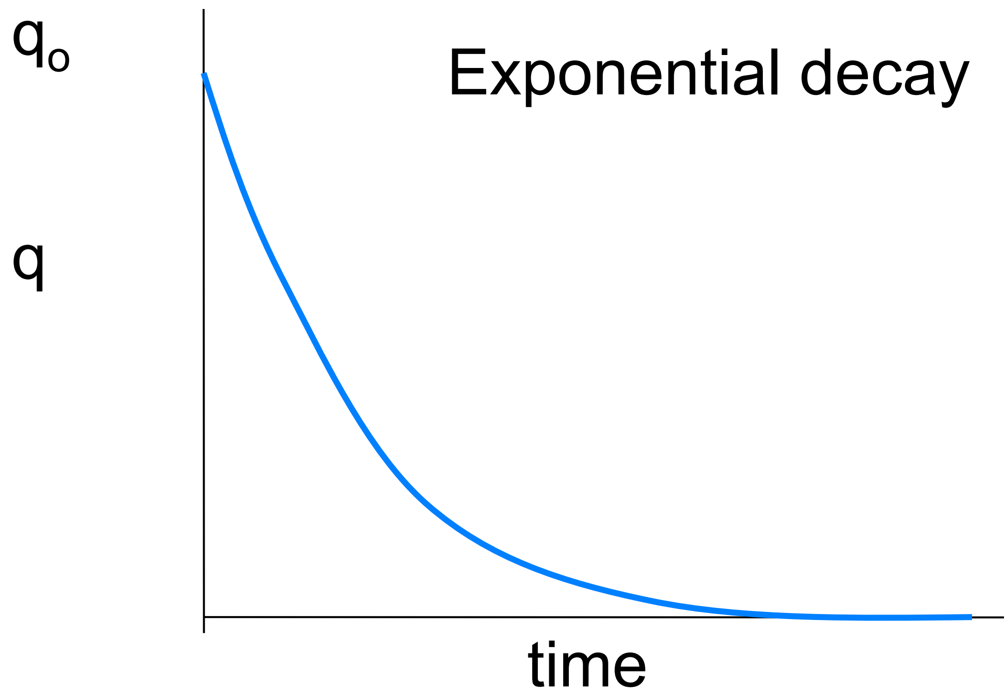
Exponential decay

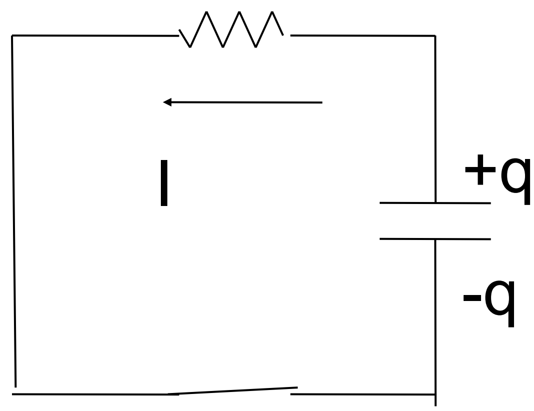




$$\Delta V_c - \Delta V_R = 0$$

Exponential decay





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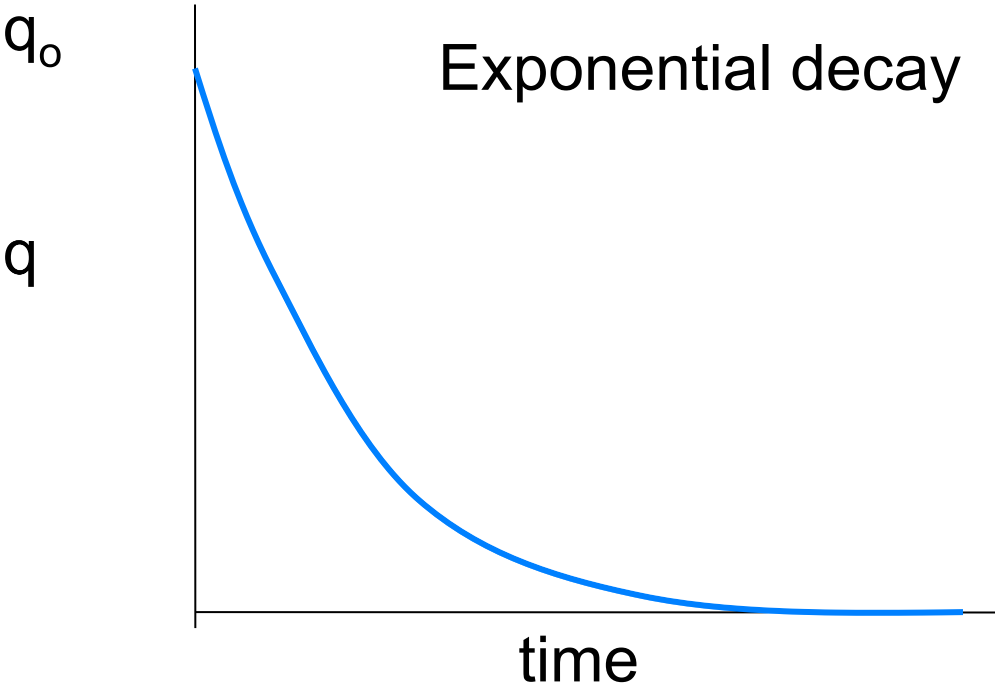
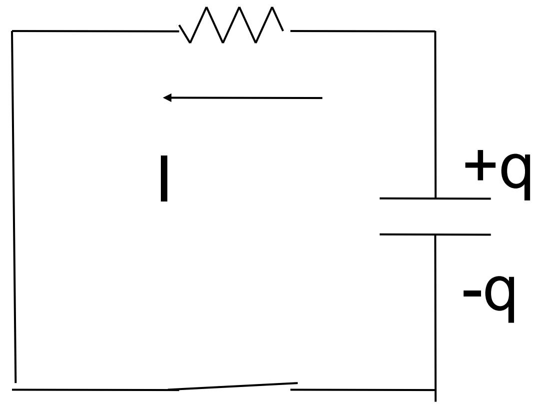




$$\Delta V_c - \Delta V_R = 0$$

short times

intermediate times

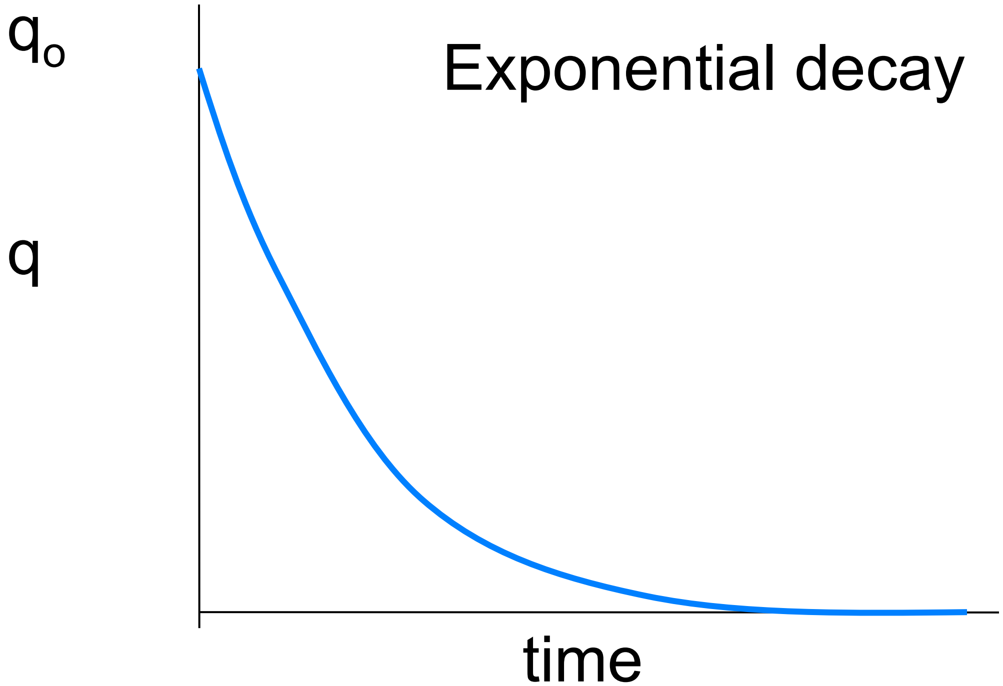
long times

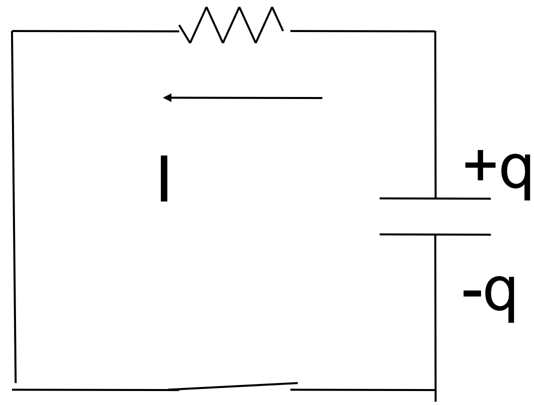
$q =$

$\Delta V_C =$

$I =$

Exponential decay





$$\Delta V_c - \Delta V_R = 0$$

short times | intermediate times | long times

$q =$ q_o

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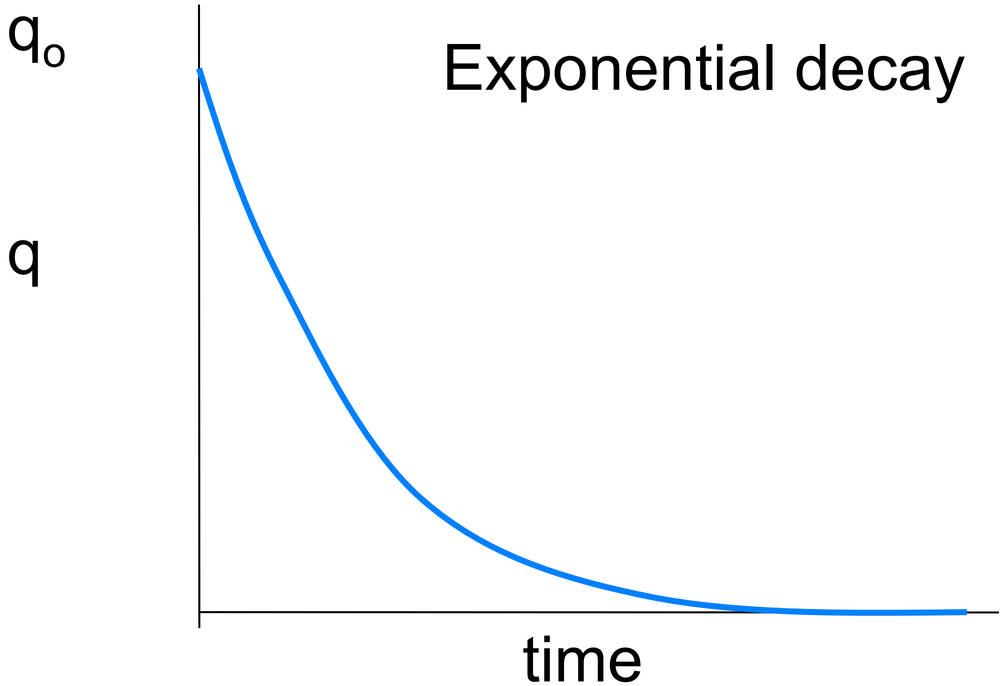
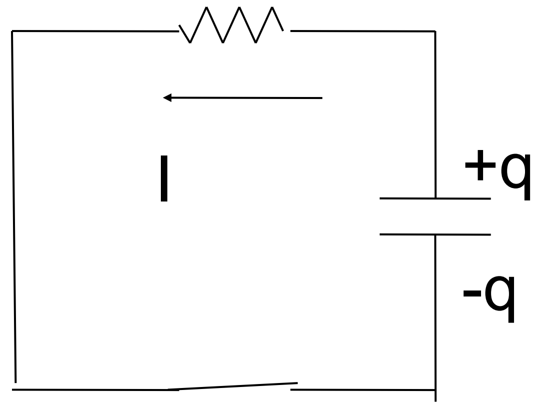
$I =$

Exponential decay





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short times	intermediate times	long times

$q = q_o$

$\Delta V_C = \Delta V_o$

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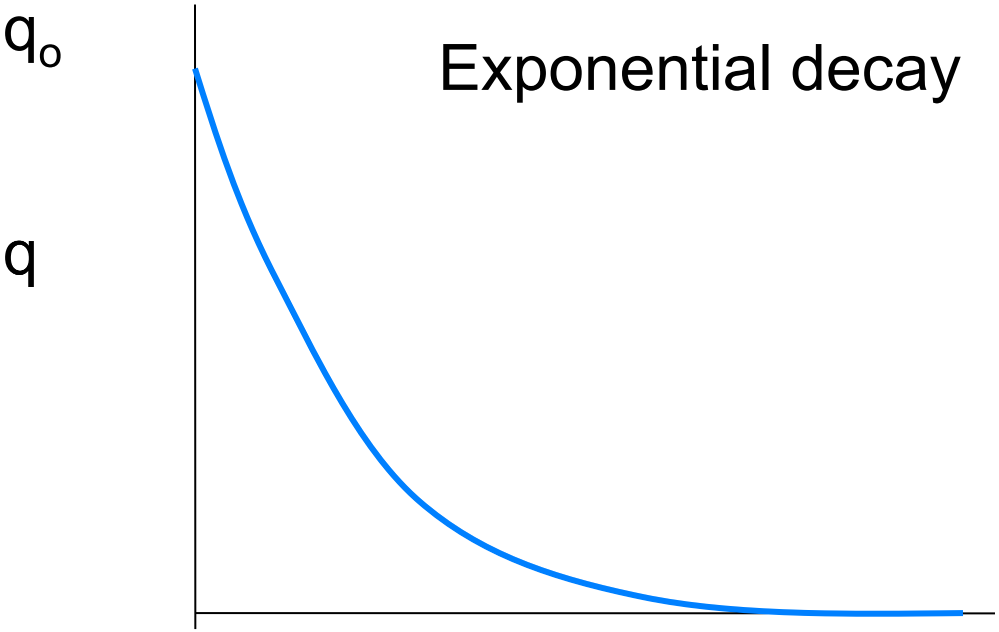
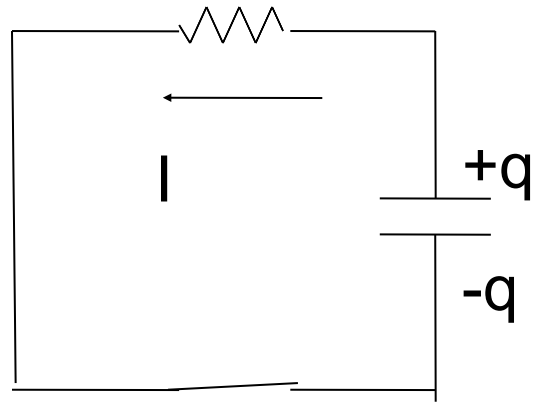
Exponential decay





$$\Delta V_c - \Delta V_R = 0$$

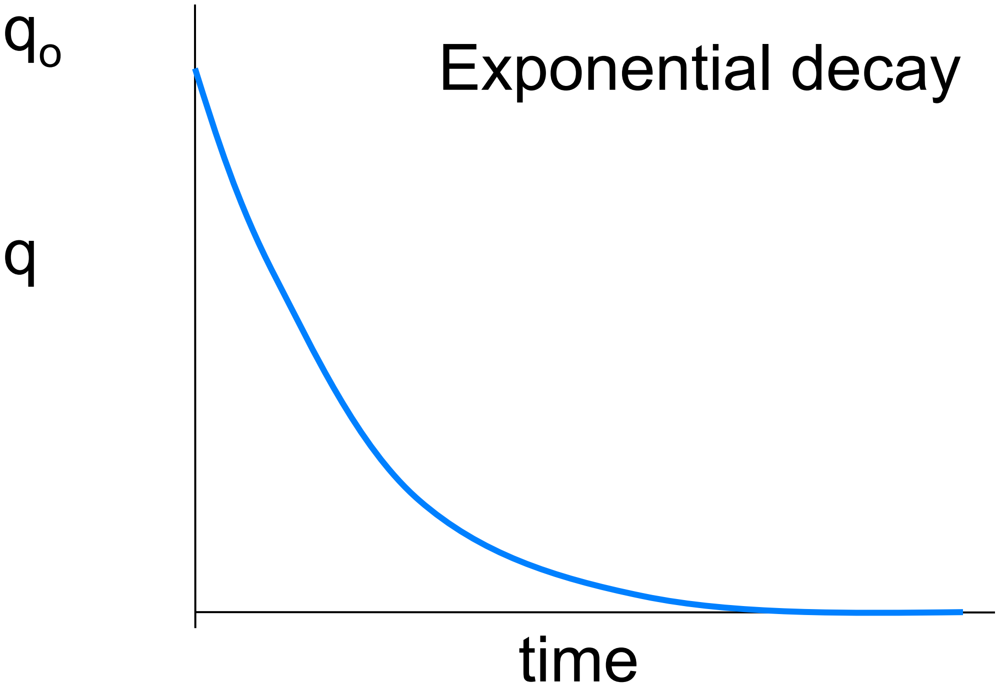
short times	intermediate times	long times

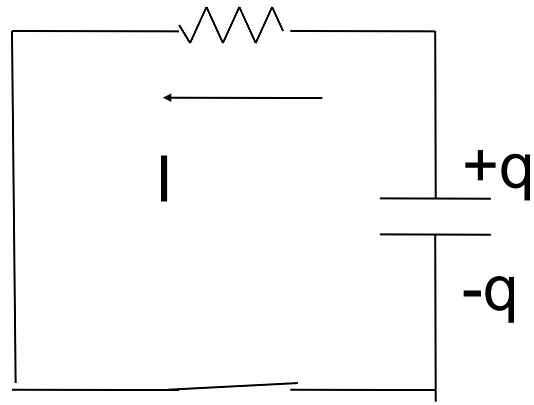
$$q = q_o$$

$$\Delta V_C = \Delta V_o$$

$$I = \frac{\Delta V_o}{R}$$

Exponential decay





$$\Delta V_c - \Delta V_R = 0$$

short times	intermediate times	long times
$q = q_o$	$q = q_o e^{-\left(\frac{t}{\tau}\right)}$	
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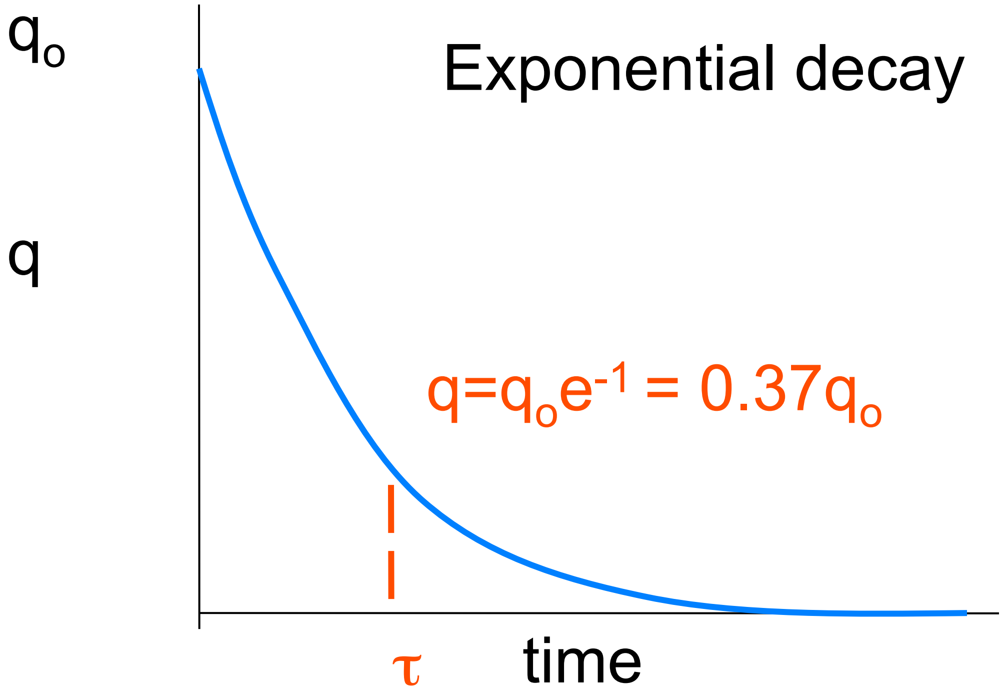
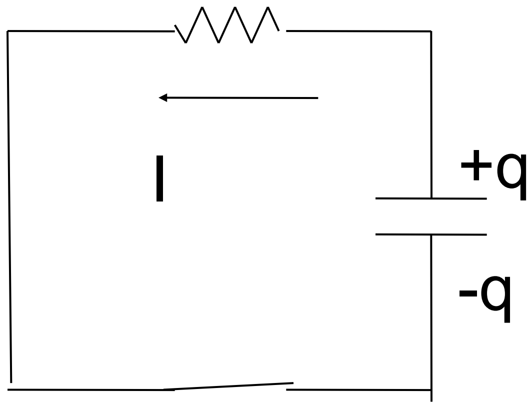
$I = \dfrac{\Delta V_o}{R}$		

Exponential decay





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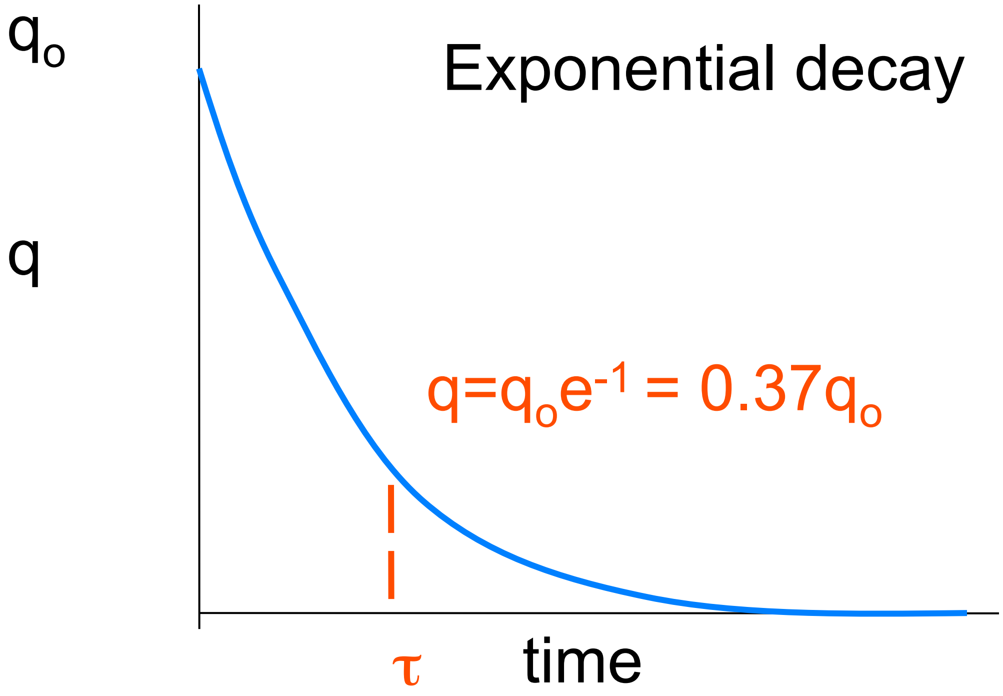
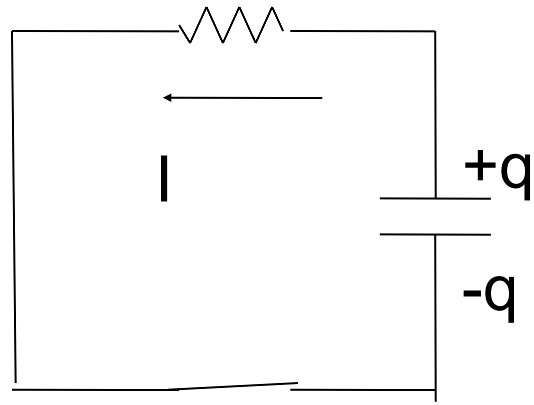
$$\tau = RC$$





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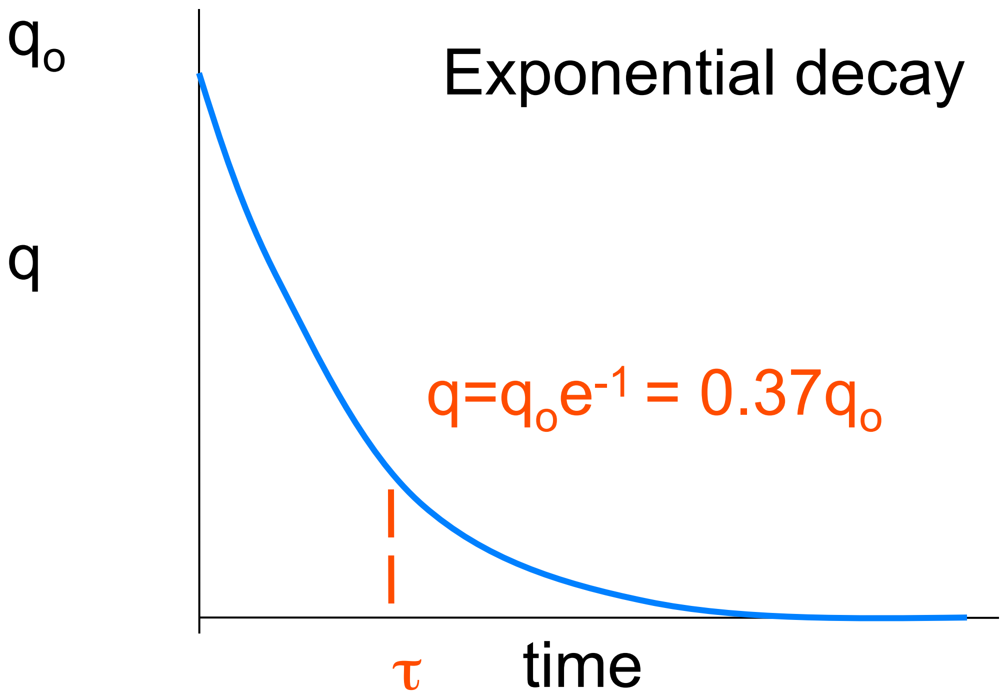

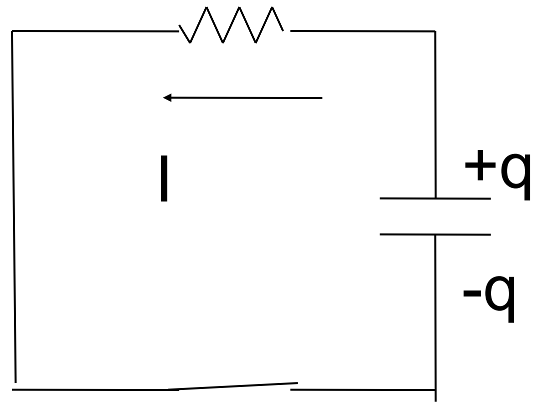

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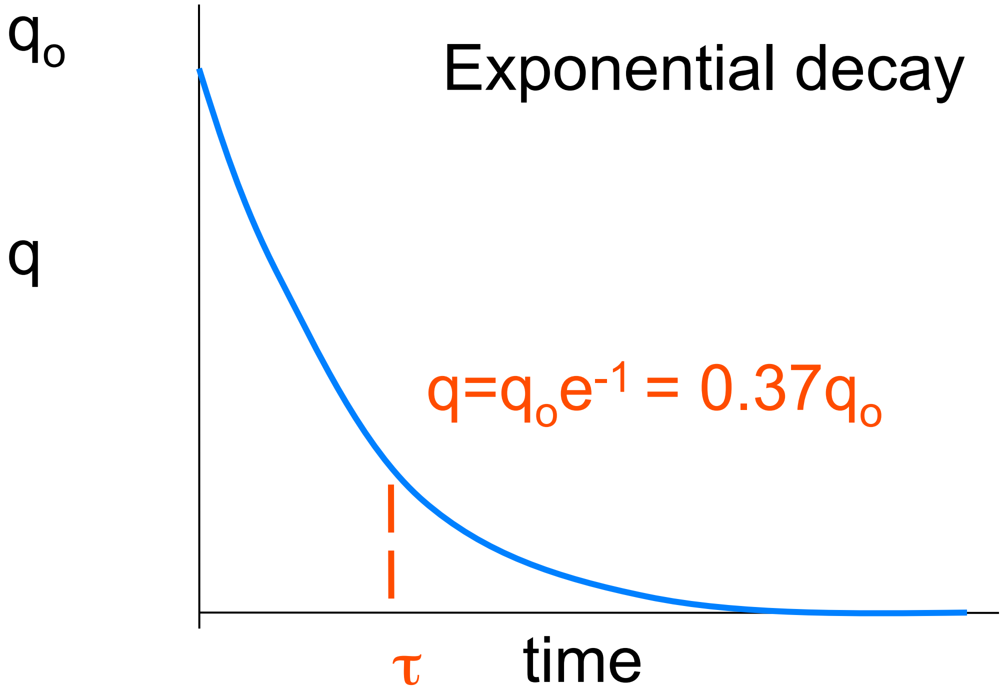

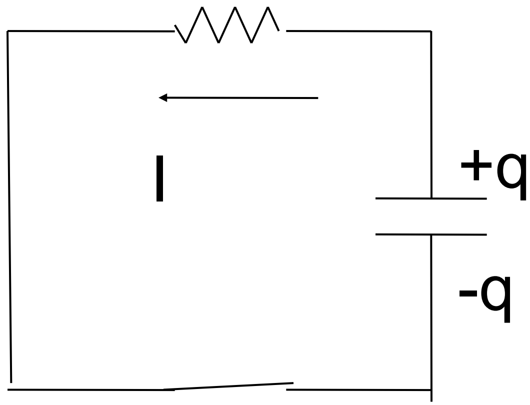

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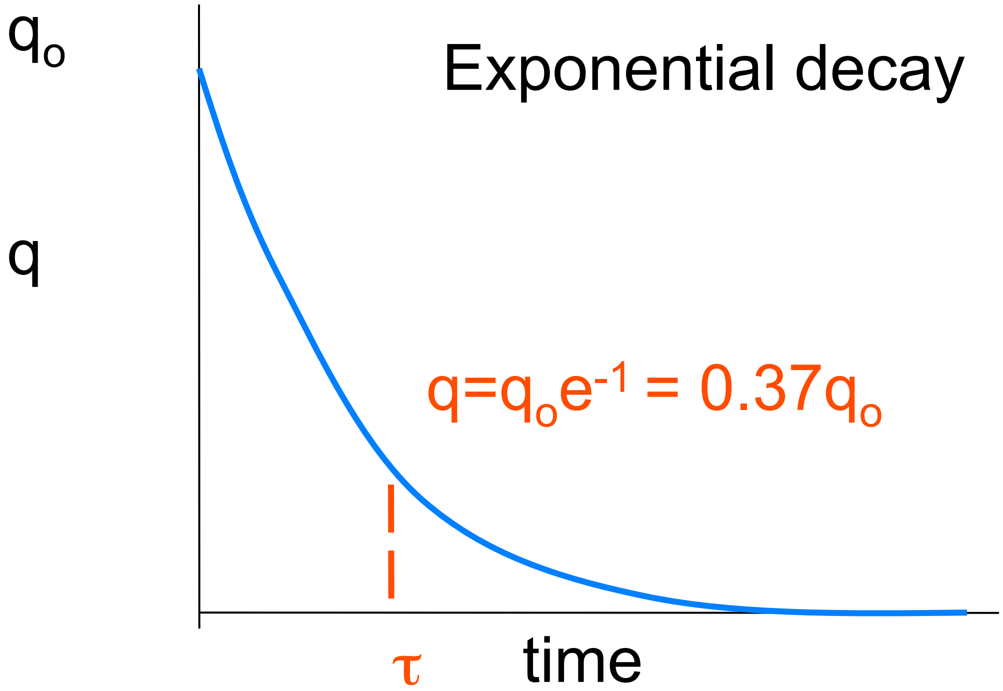

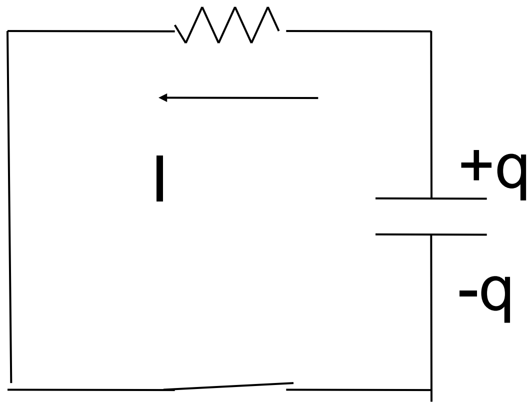

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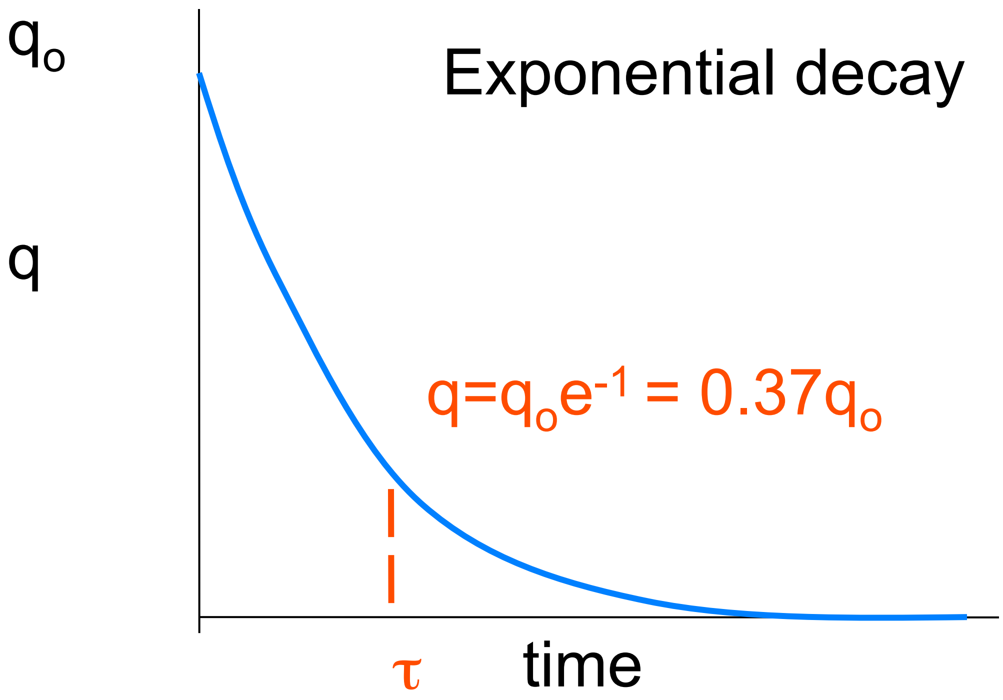

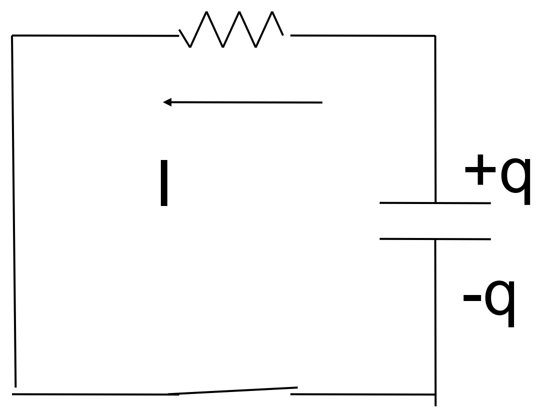

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$$\tau = RC$$

Exponential decay

Found in many other systems-
Chemical reaction, nuclear decay

A ® B

When the rate of decay of a species is proportional to the amount of the species

$$\frac{\Delta A}{\Delta t} = -\frac{A}{\tau}$$

The result is exponential decay

$$A = A_o e^{-\left(\frac{t}{\tau}\right)}$$

τ is a constant

A 12 μfarad capacitor is discharged through a 2 kΩ resistor. How long does it take for the voltage to decay to 5% of the initial voltage.

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$$\frac{V}{V_o} = e^{-\left(\frac{t}{\tau}\right)}$$

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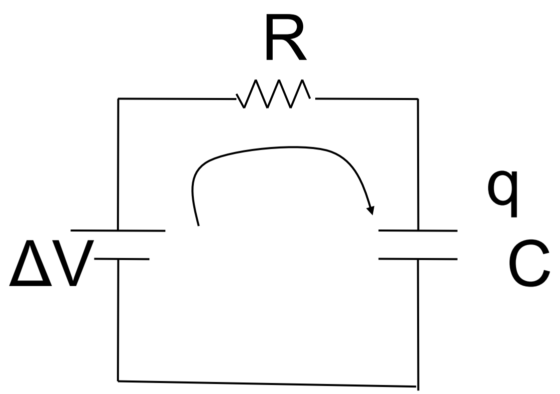
$$\ln\left(\frac{V}{V_o}\right) = -\frac{t}{\tau}$$

$$t = -\tau \ln\frac{V}{V_o} = -24x10^{-3}(\ln(0.05)) = 7.2x10^{-2}s$$

33. Consider a series RC circuit for which R=1.0 MΩ, C=5.0 μF and ε=30 V. The capacitor is initially uncharged when the switch is open. (a) Find the charge on the capacitor 10 s after the switch is closed.



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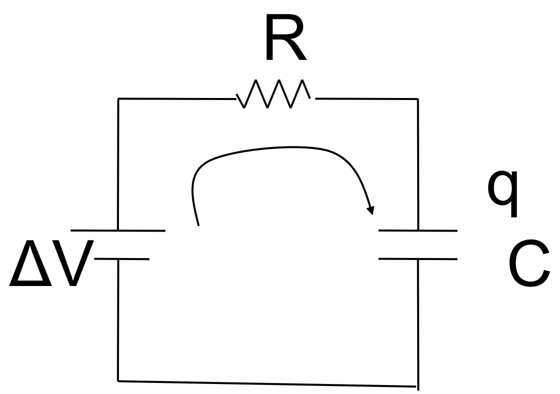

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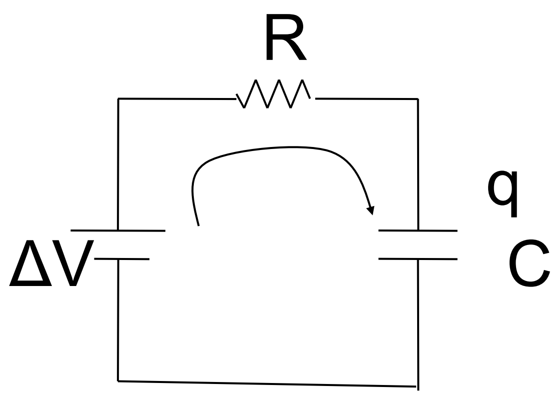

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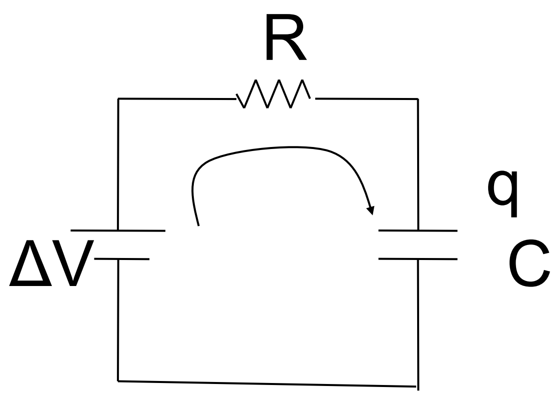

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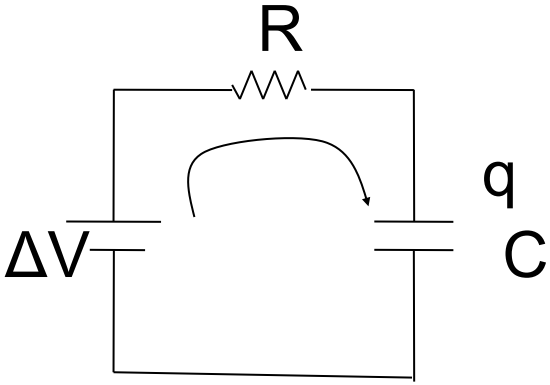

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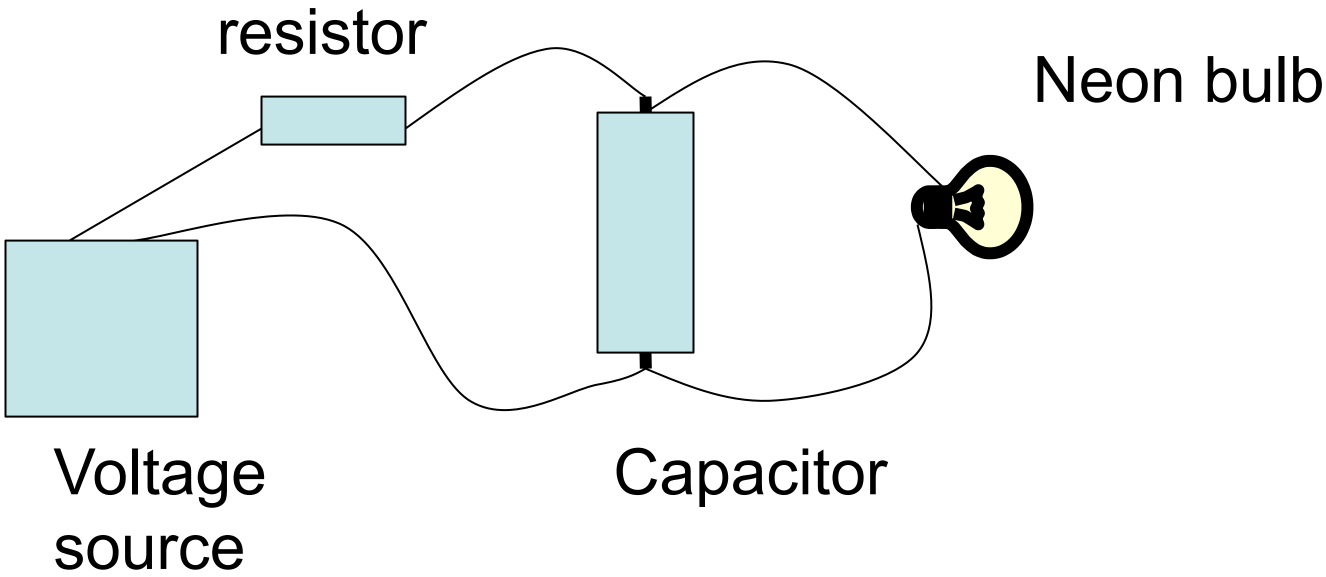
$$q = q_o(1 - e^{-\frac{t}{RC}}) = 1.5x10^{-4}(1 - e^{-\frac{10}{5}})$$

$$q = 1.3x10^{-4}C$$

You plan to make a flasher circuit that charges a capacitor through a resistor up to a voltage at which a neon bulb discharges (about 100V) about once every 5 sec. If you have a 10 microfarad capacitor what resistor do you need?

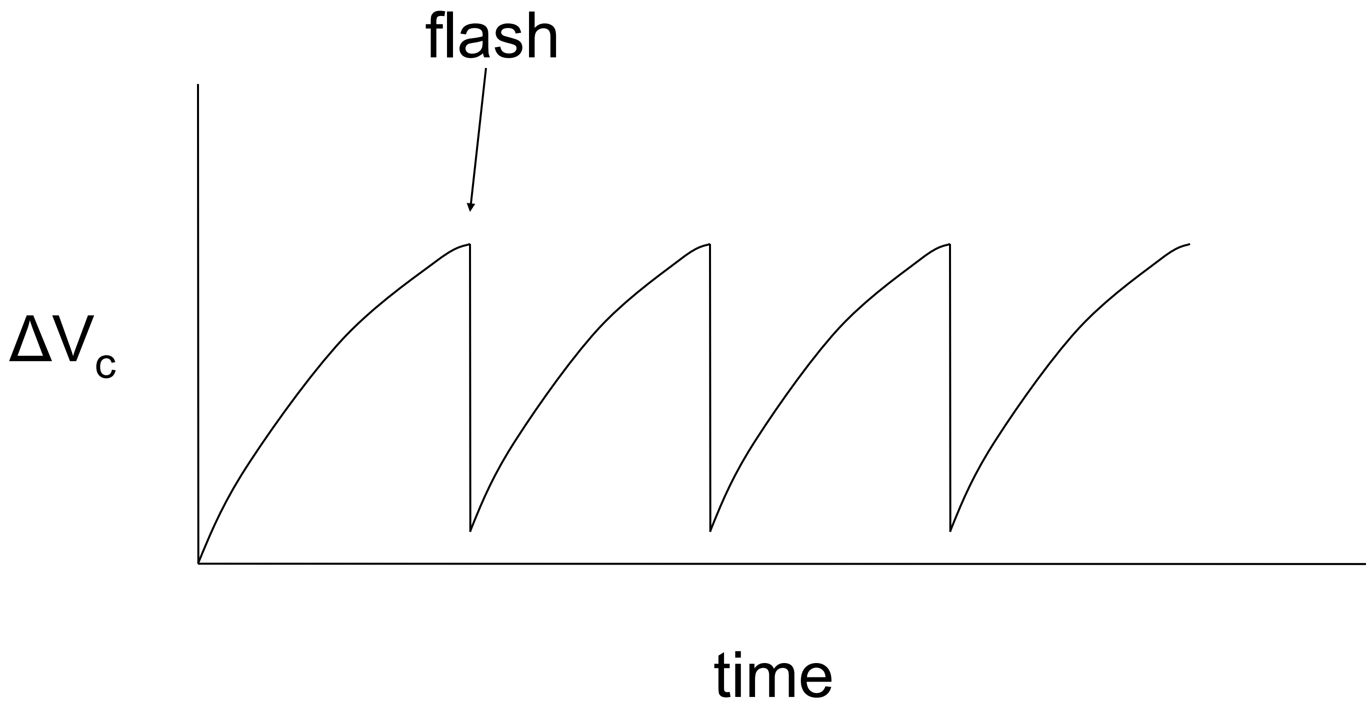


$$\tau = RC$$

$$R = \frac{\tau}{C} = \frac{5}{10x10^{-6}} = 0.5x10^{6}\,\Omega$$

About 0.5MΩ

Charging



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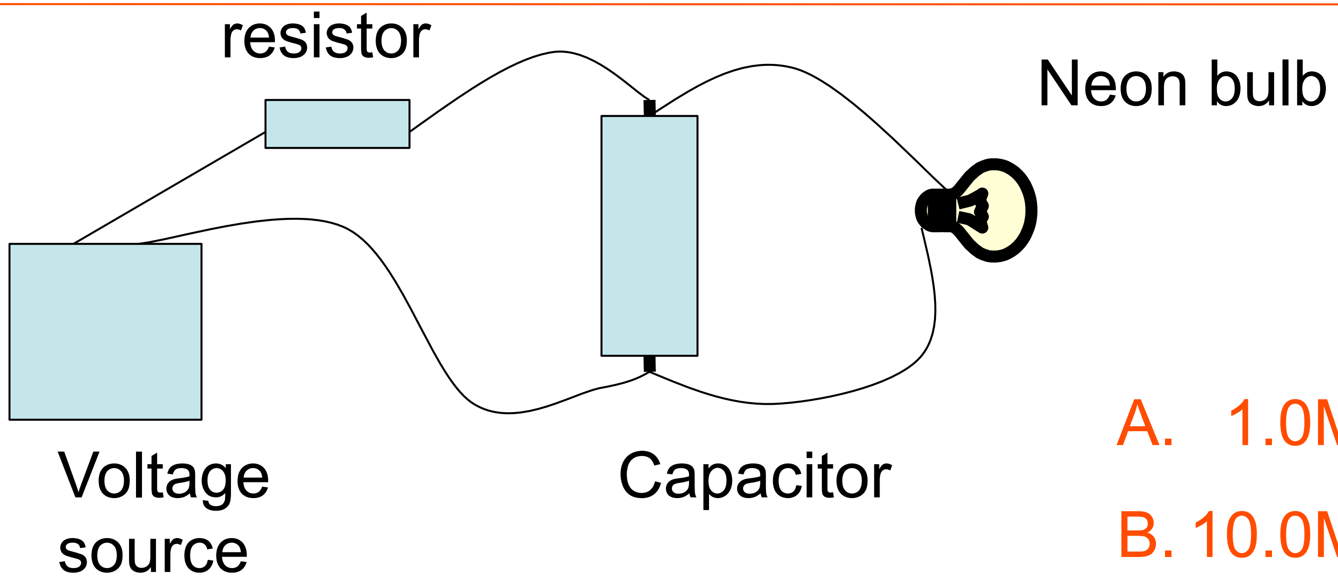


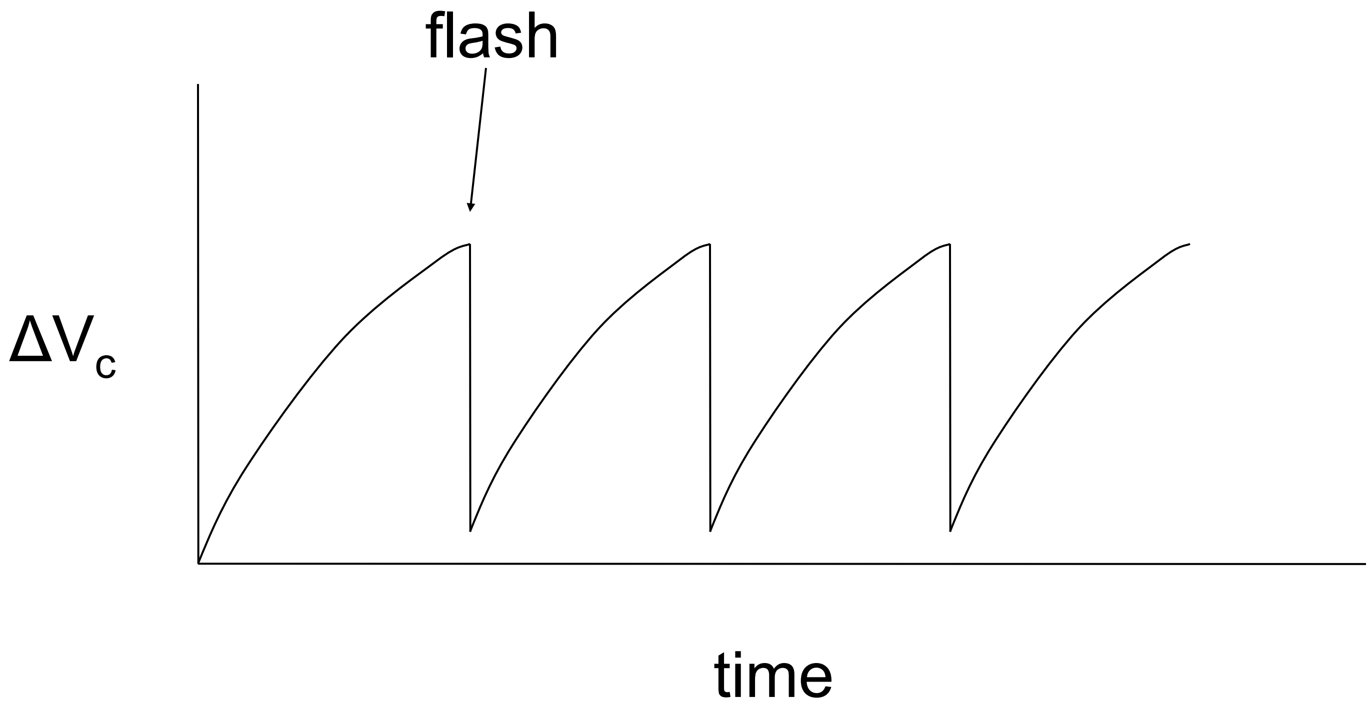
A. 1.0MΩ

B. 10.0MΩ

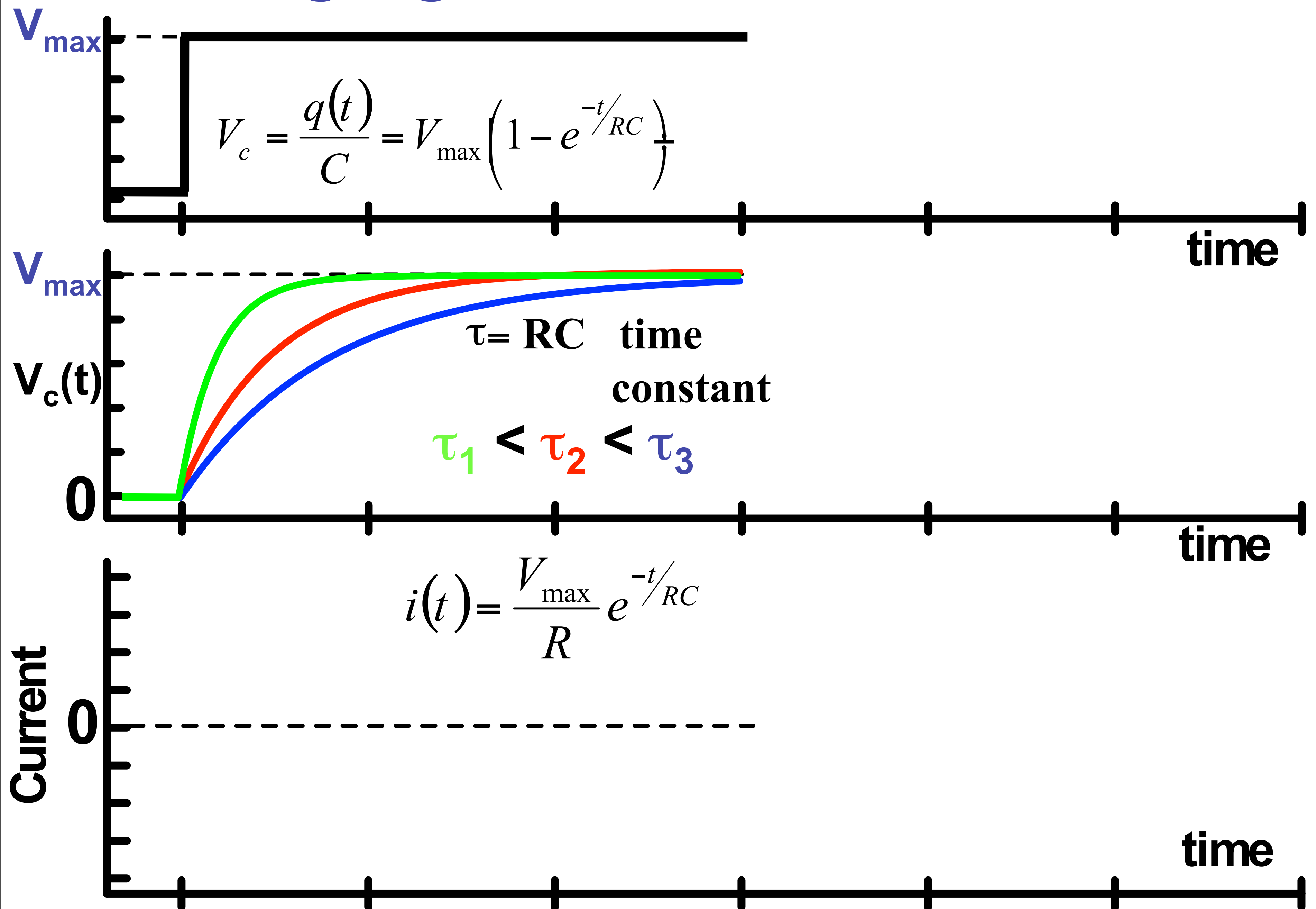
C. 5.0MΩ

D. 0.5MΩ

Charging

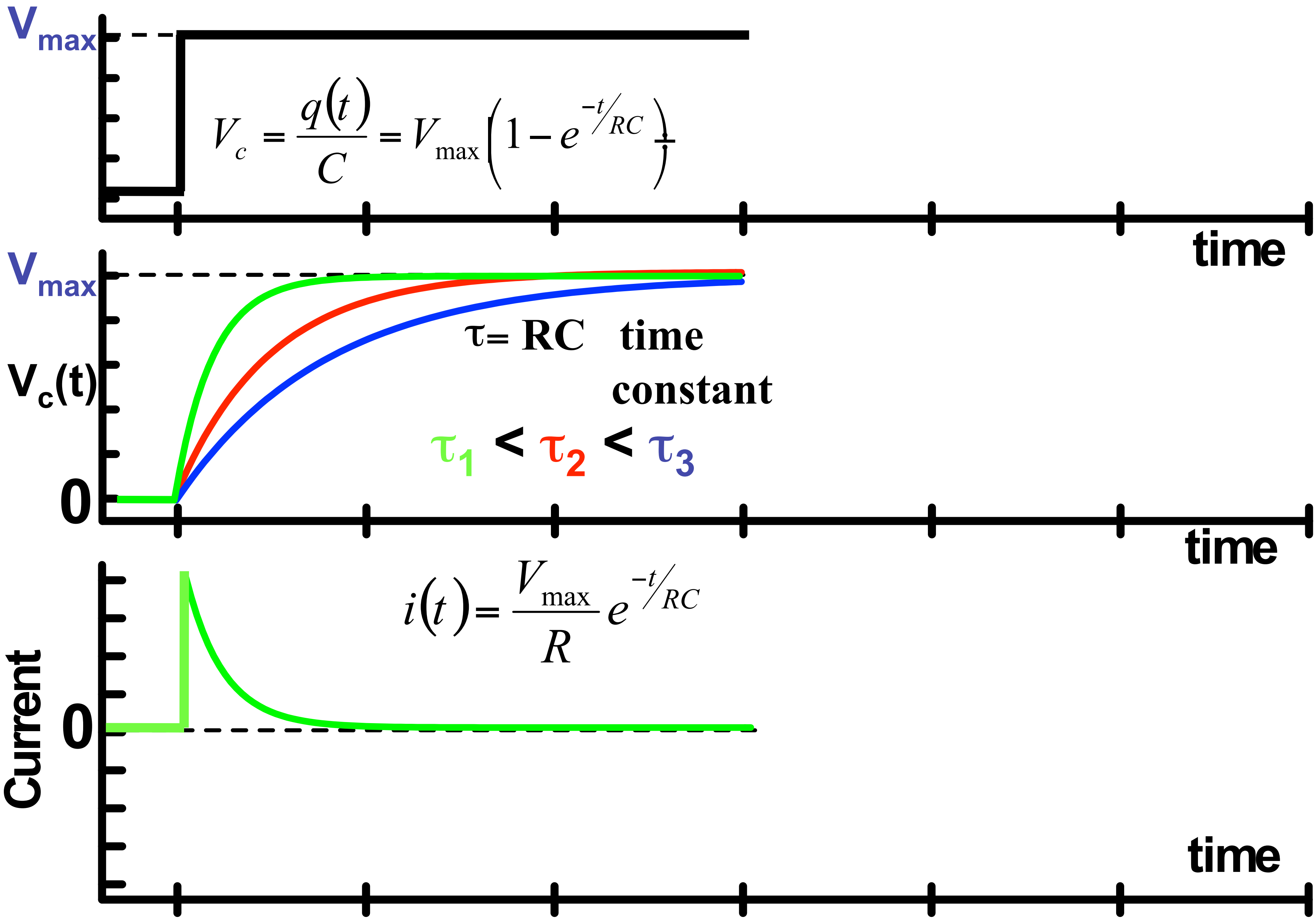


RC: charging



V_{max}
$V_c = \frac{q(t)}{C} = V_{max}\left(1 - e^{-t/RC}\right)$
time
V_{max}
$V_c(t)$
0
τ= RC time constant
$\tau_1 < \tau_2 < \tau_3$
time
$i(t) = \frac{V_{max}}{R} e^{-t/RC}$
Current
0
time

RC: charging


V_{max}
$V_c = \frac{q(t)}{C} = V_{max}\left(1 - e^{-t/RC}\right)$
time
V_{max}
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Current
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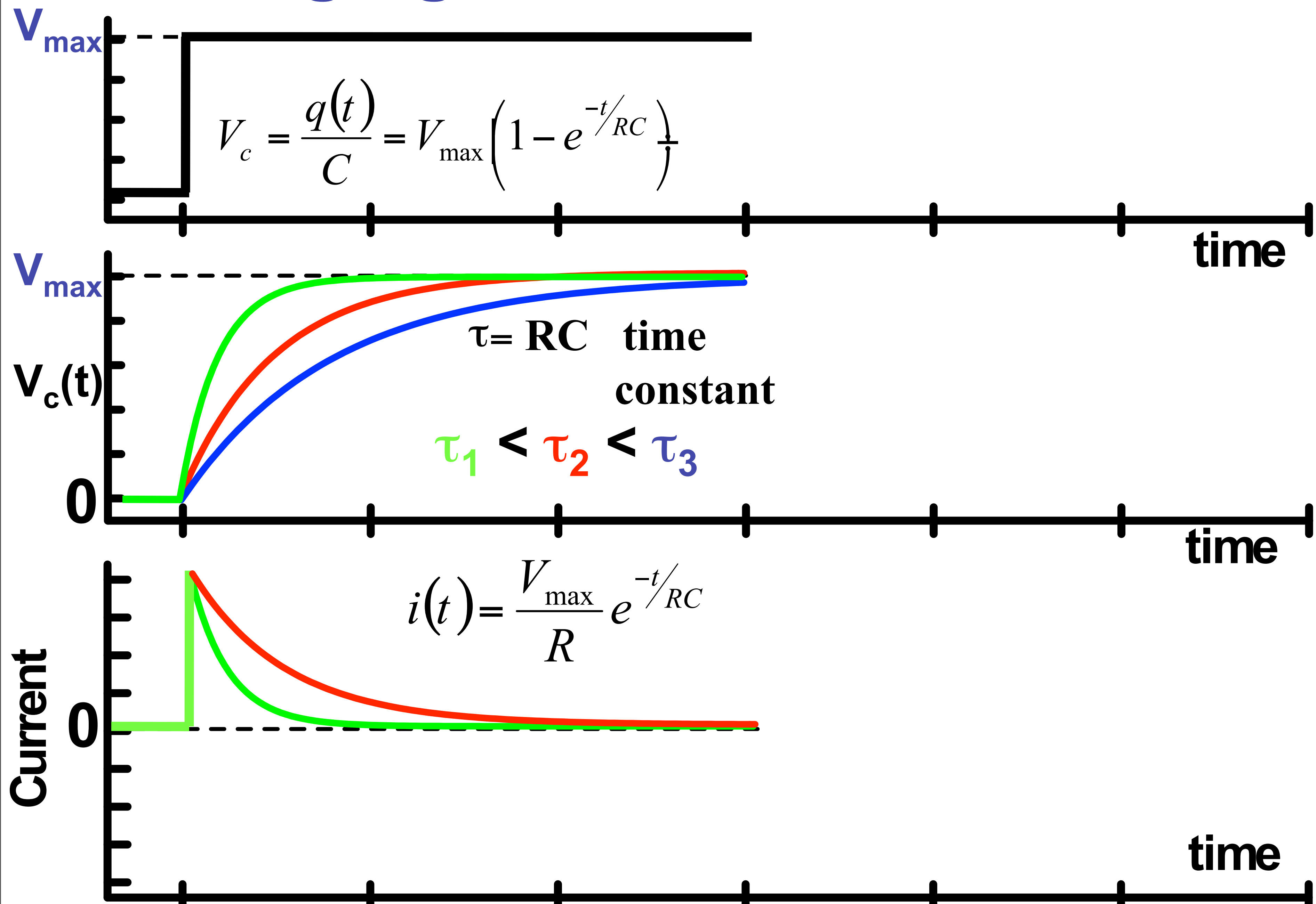
time

RC: charging



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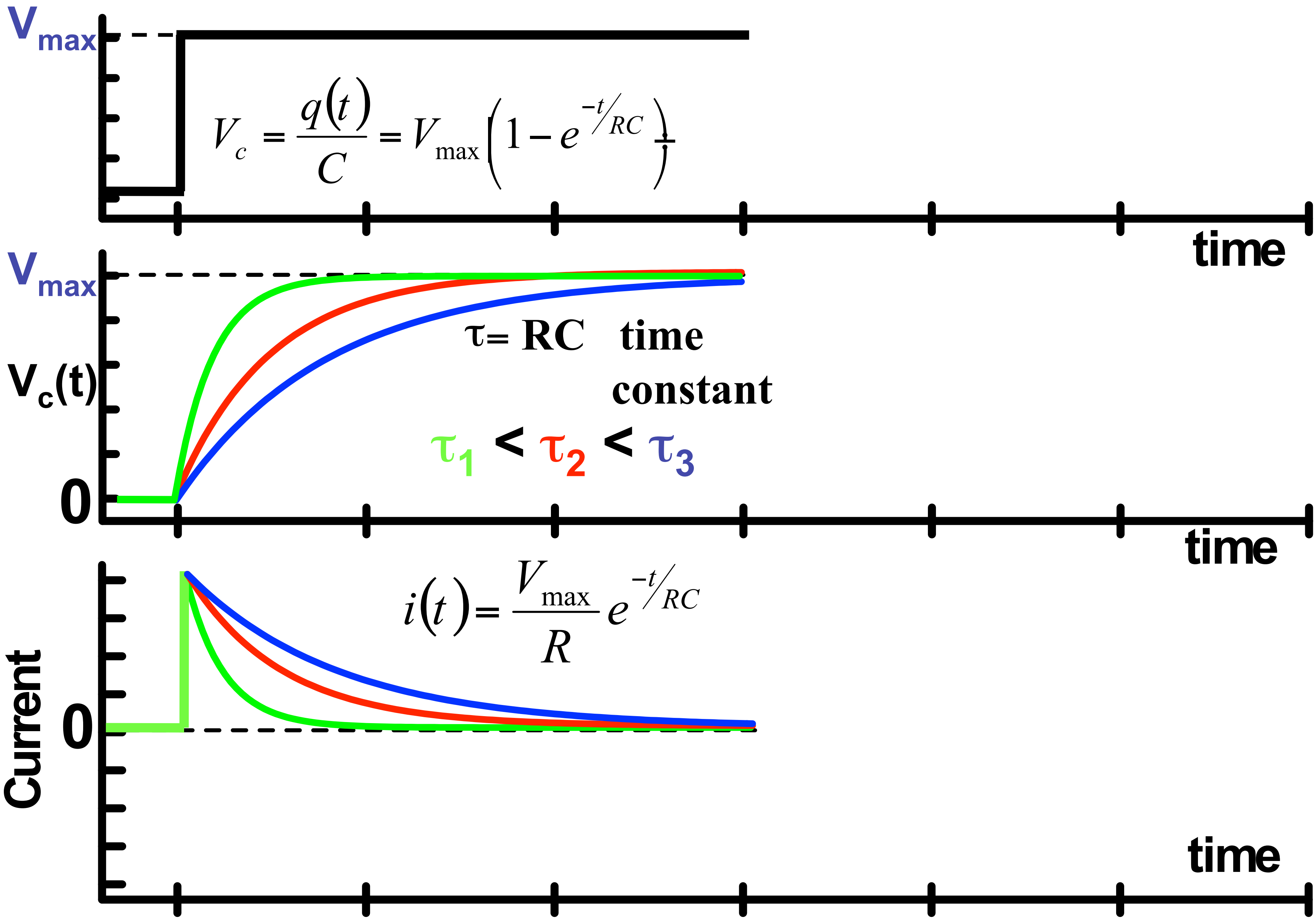

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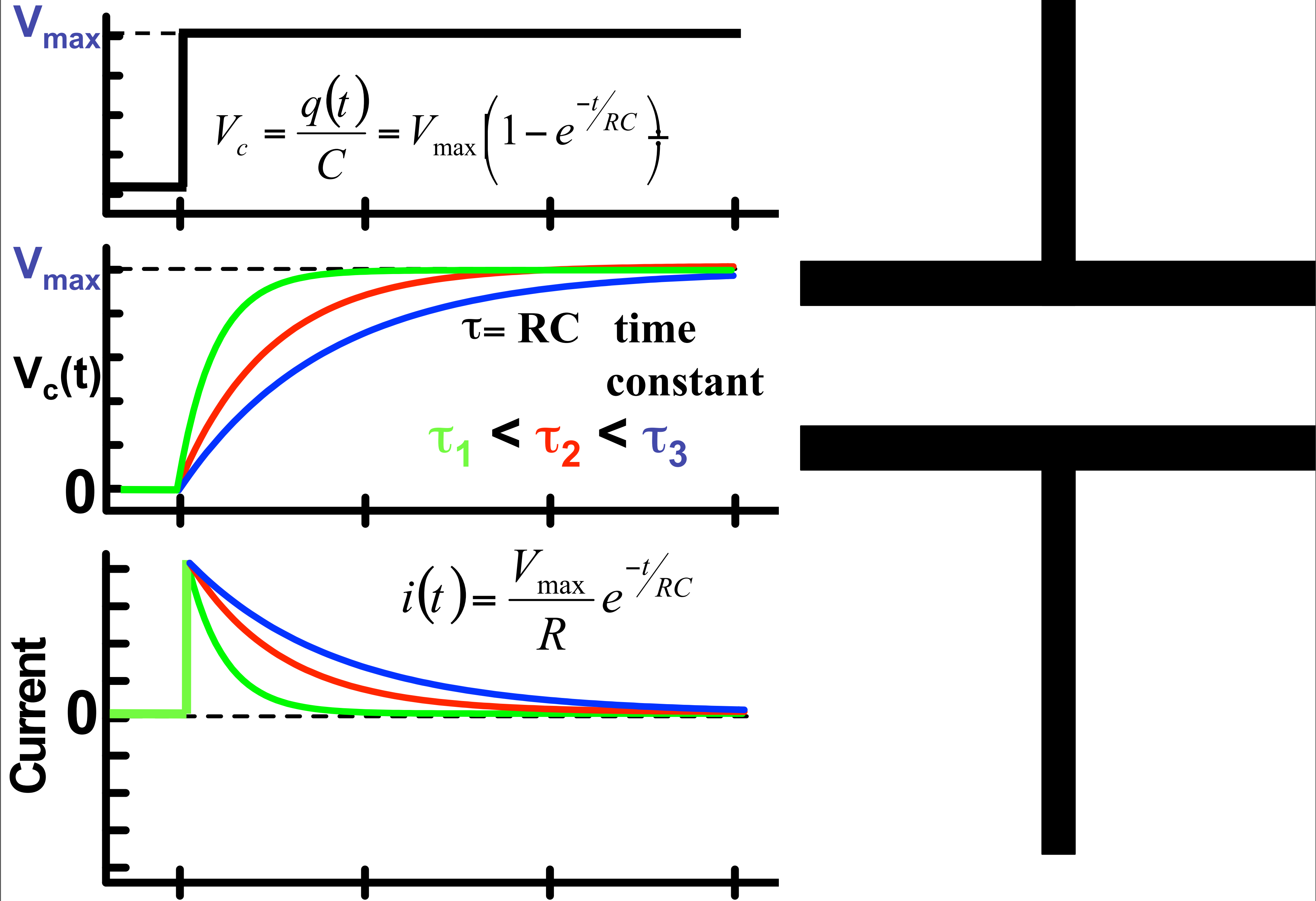
RC: charging



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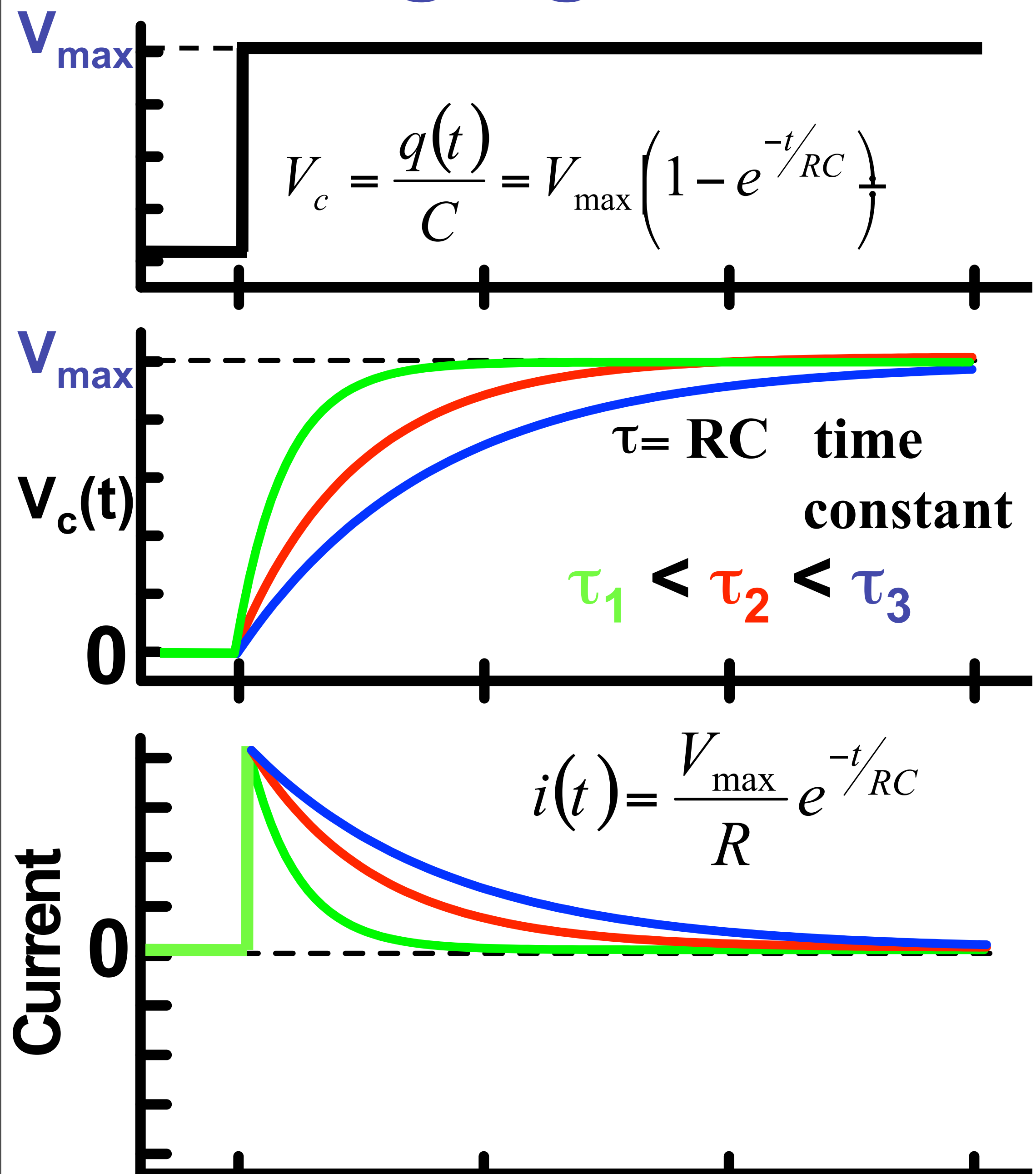
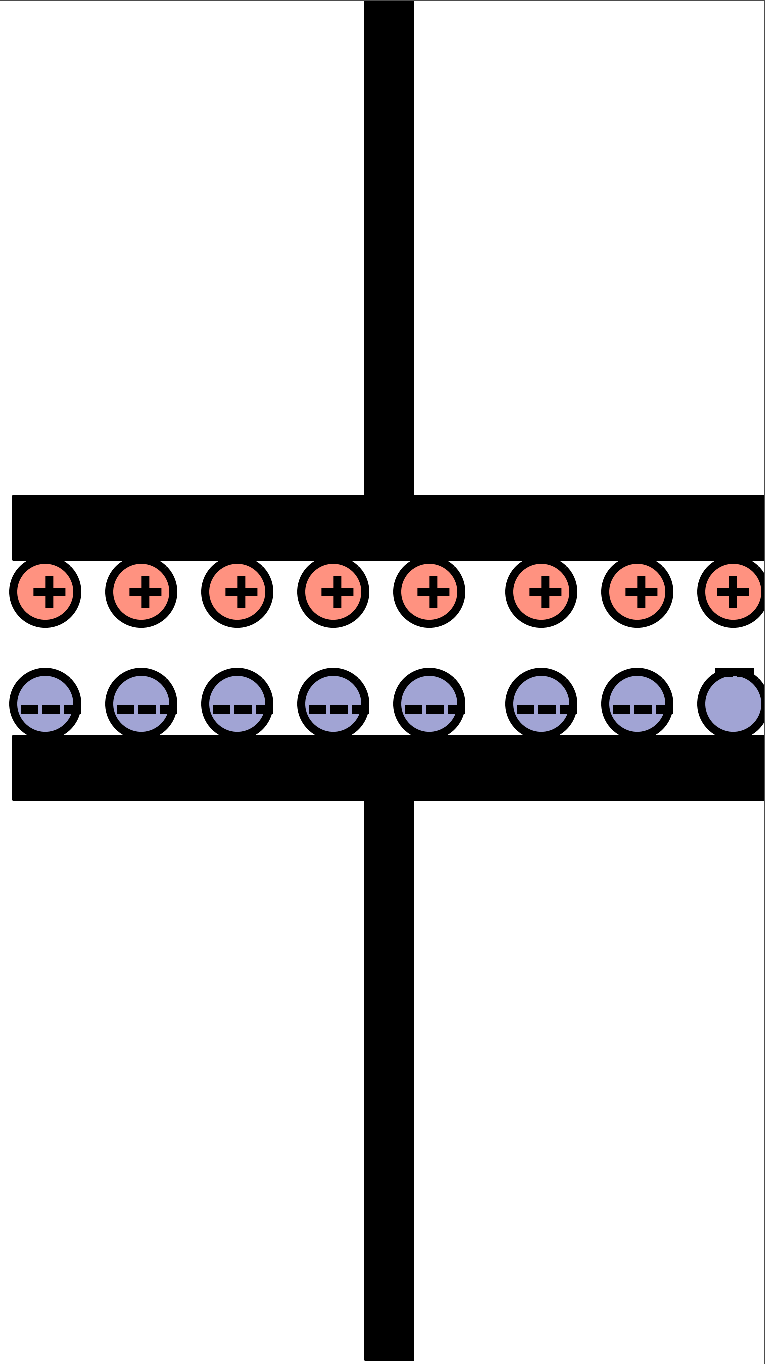
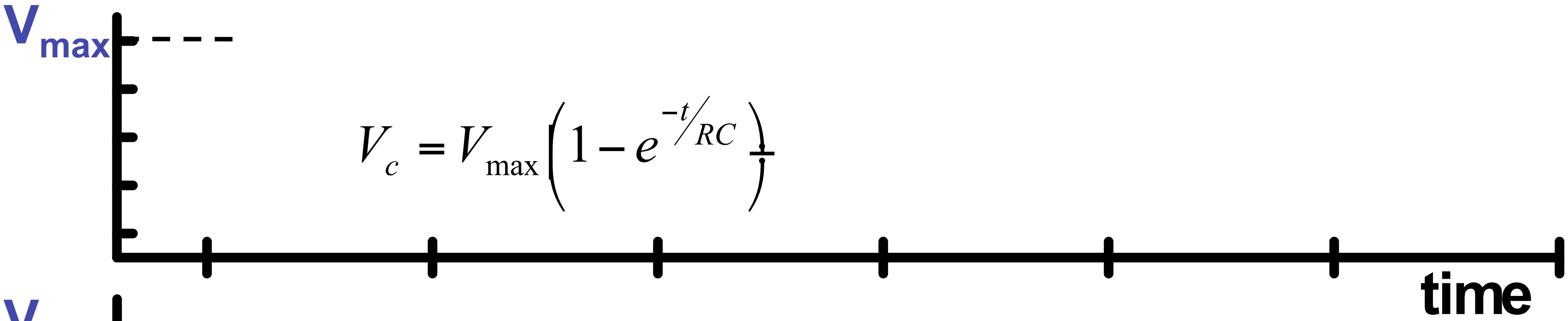
V_{max}
$V_c(t)$
0
τ= RC time constant
$\tau_1 < \tau_2 < \tau_3$
$i(t) = \frac{V_{max}}{R} e^{-t/RC}$
Current
0

RC: charging

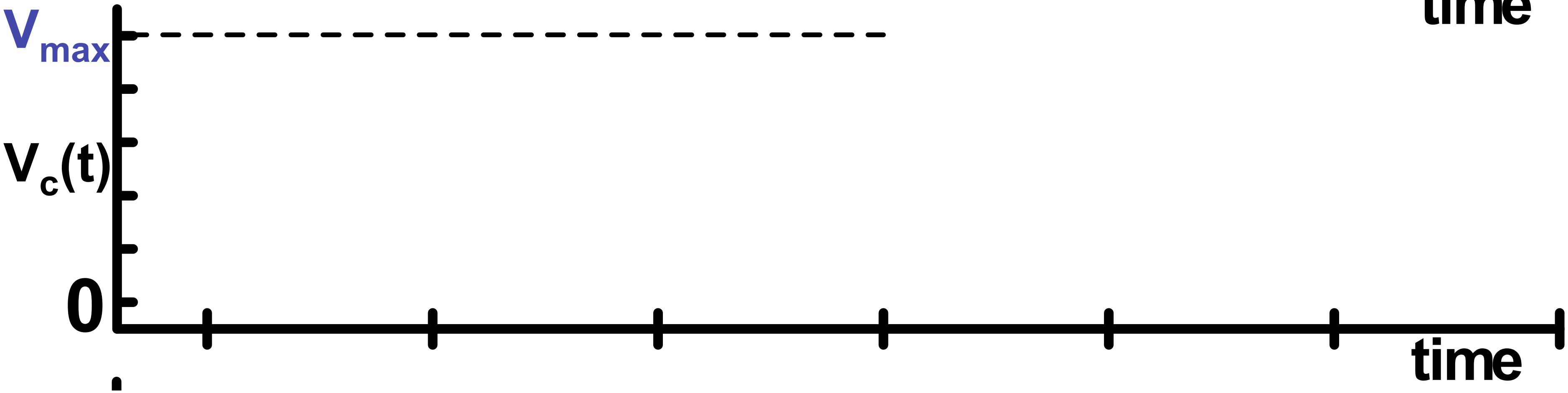

V max
$V_c = \frac{q(t)}{C} = V_{max}\left(1 - e^{-t/RC}\right)$
V max
V c (t)
0
τ= RC time constant
τ 1 < τ 2 < τ 3
$i(t) = \frac{V_{max}}{R} e^{-t/RC}$
Current
0



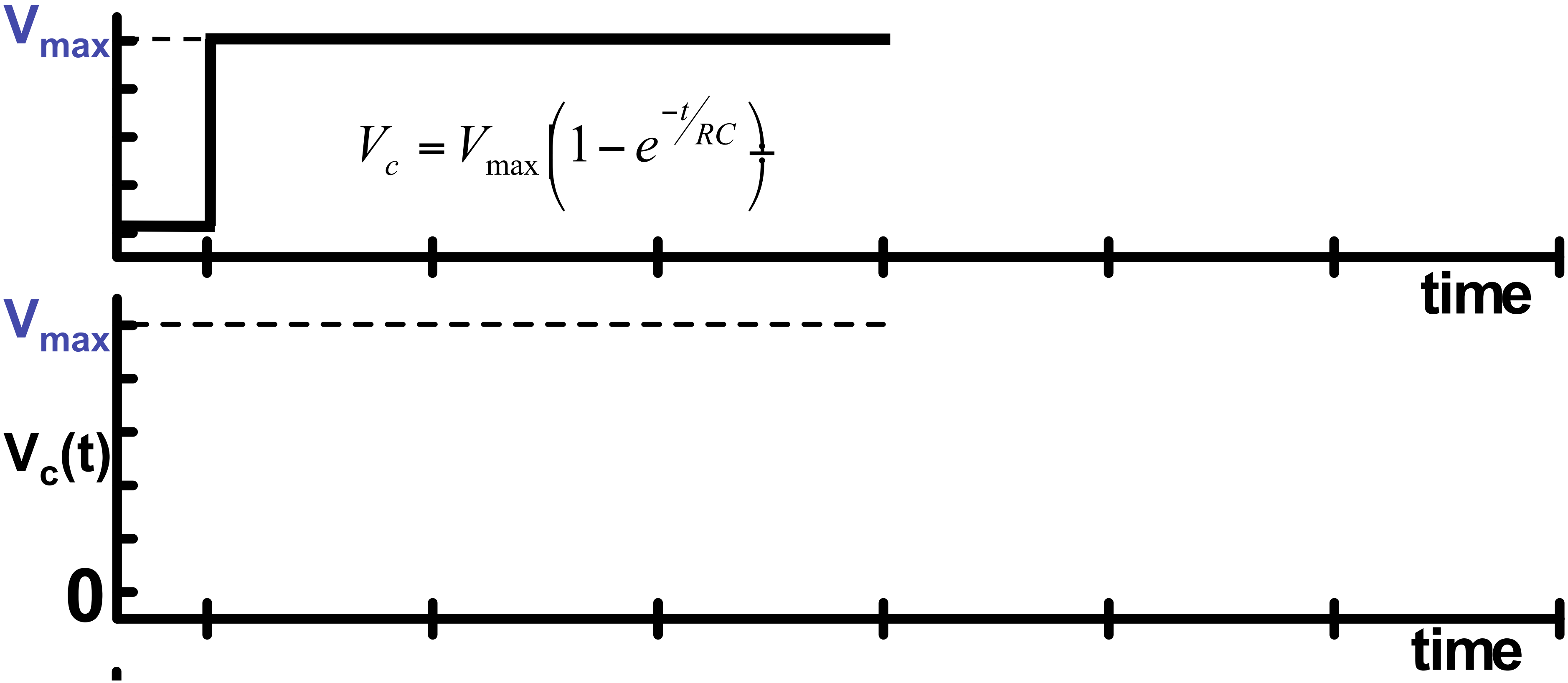
RC: charging



$$V_c = V_{max}\left(1 - e^{-t/RC}\right)$$



RC: charging



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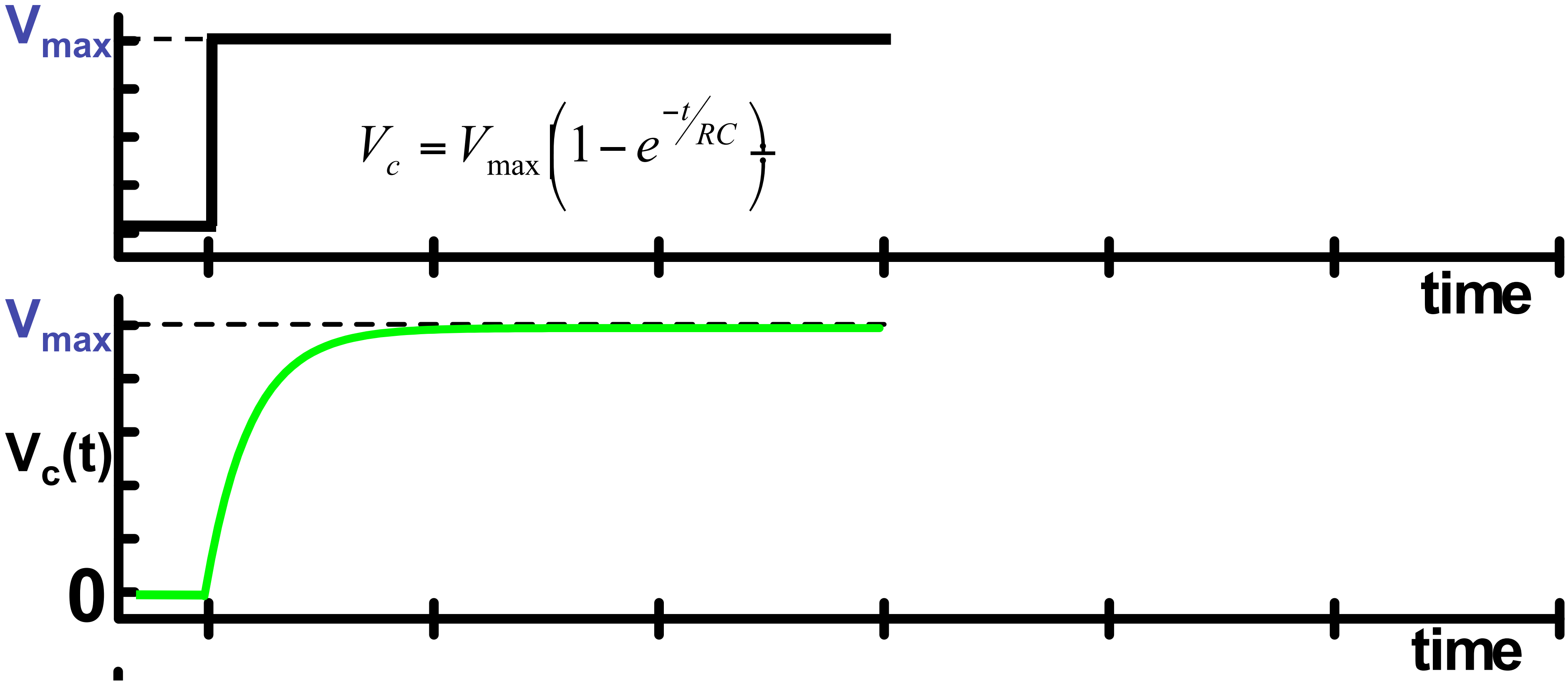
RC: charging



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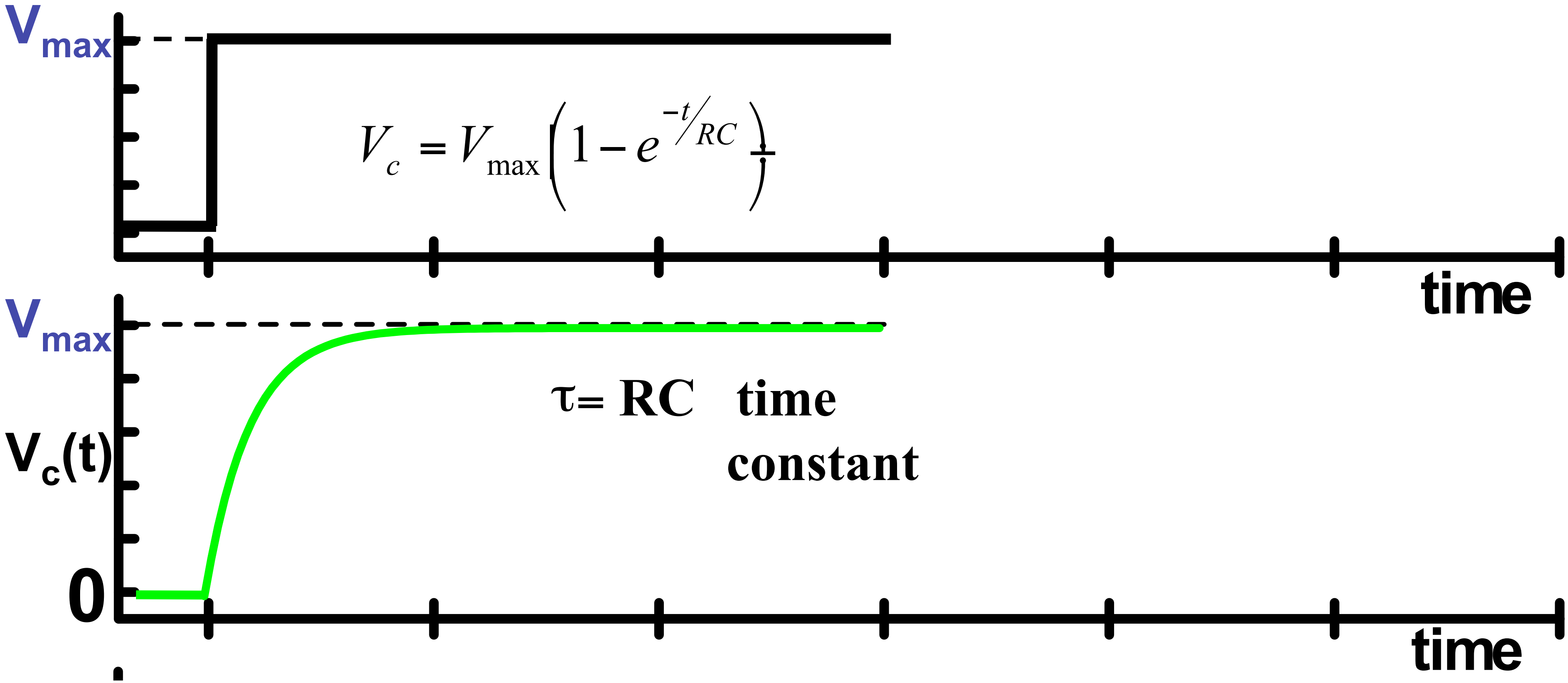

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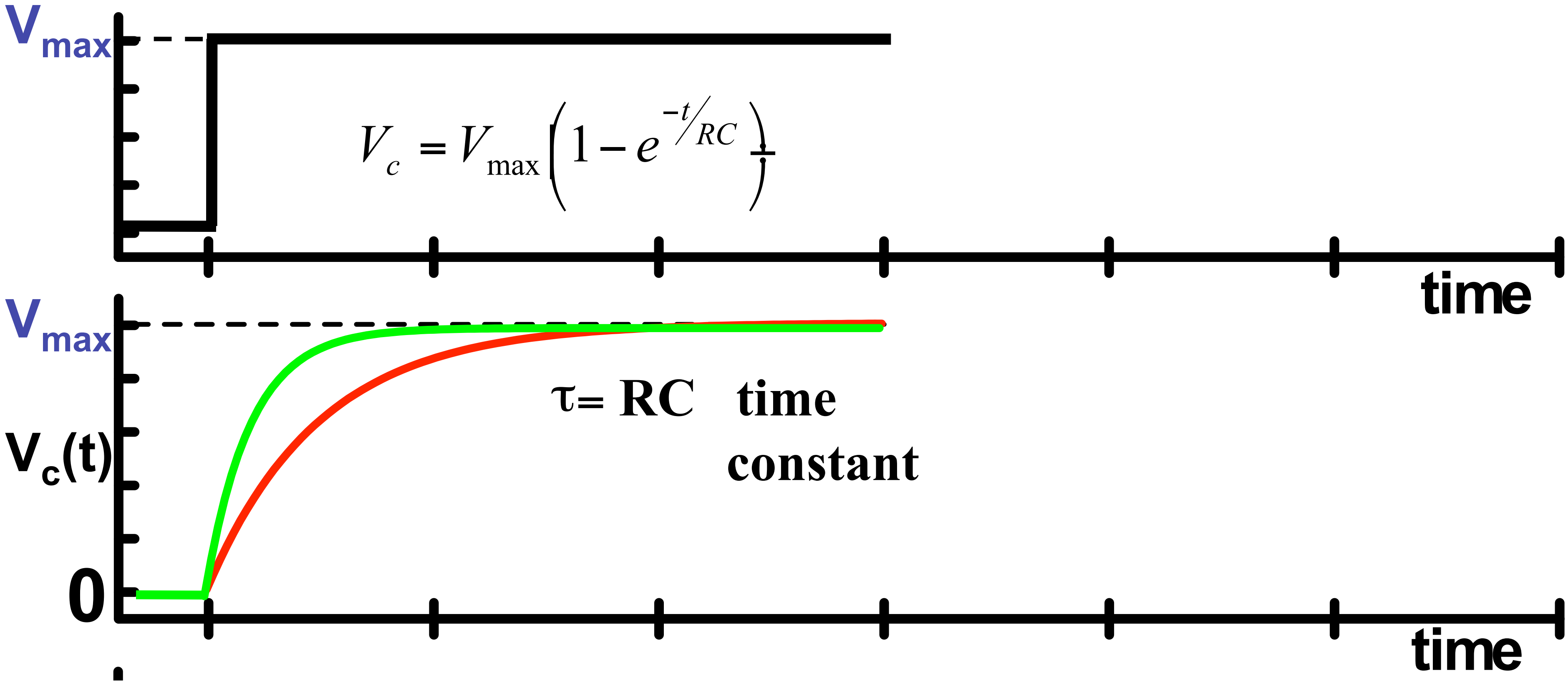

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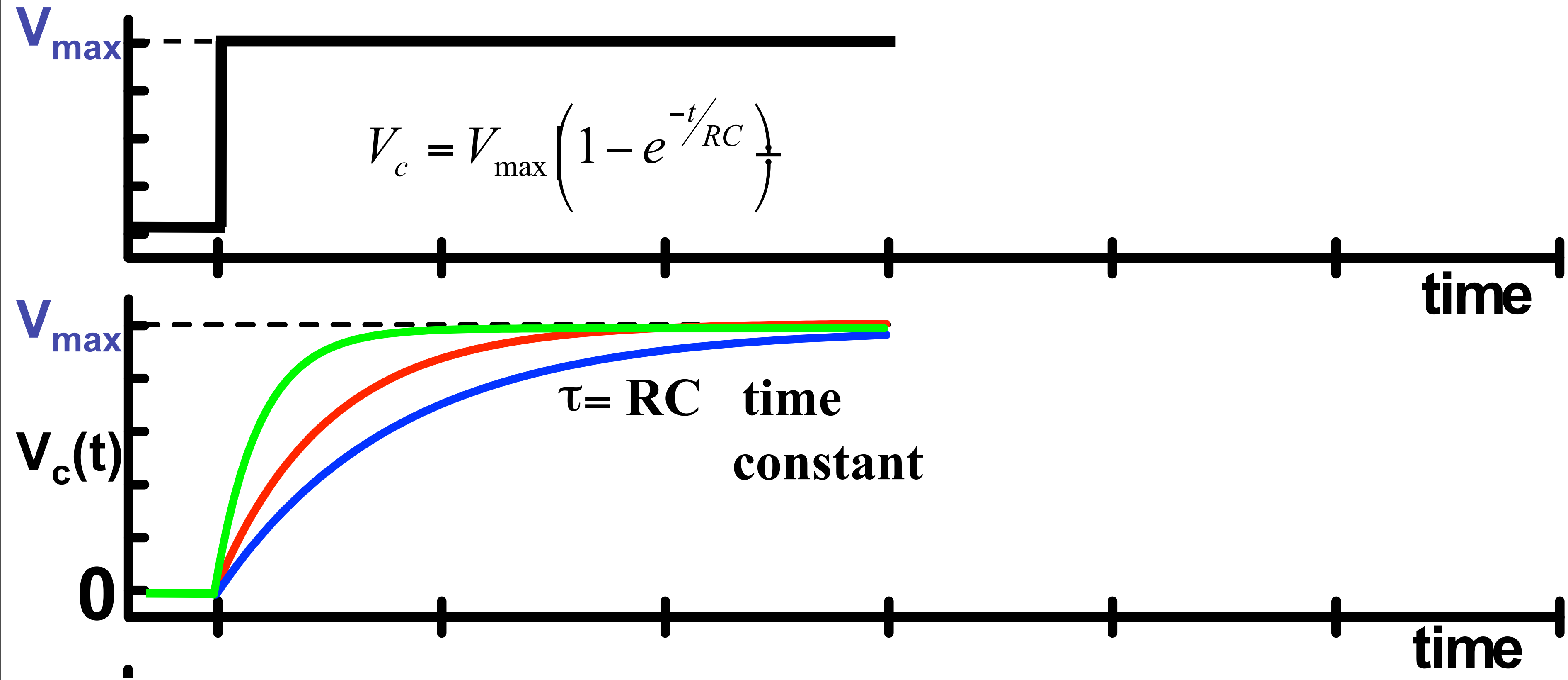

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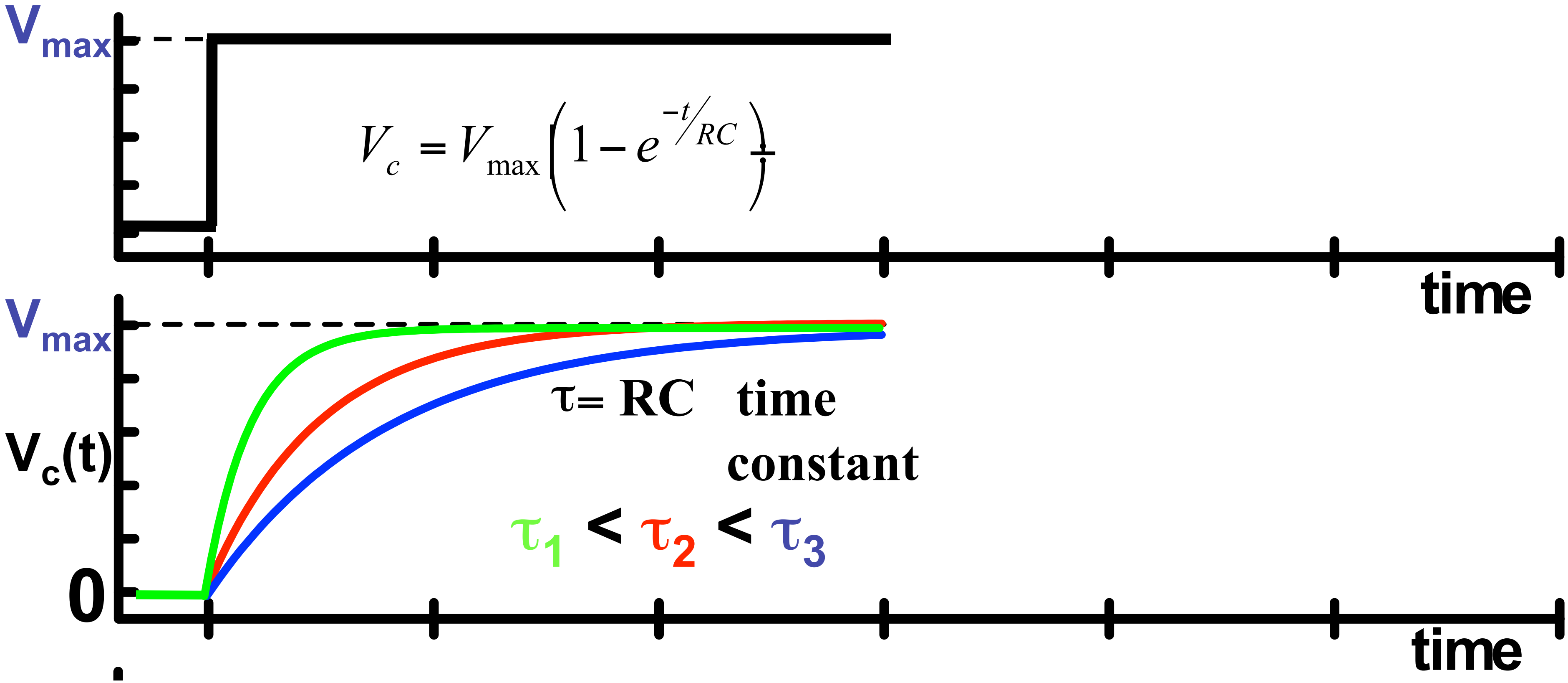

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HW – Clickers Out