Physics 122 – Class #25 – (4/14/15)

- Review of Kirchoff's Laws
- Analyzing Series and Parallel Circuits
  - Equivalent resistance
- Internal resistance of a battery
- RC Circuits

Announcements

- Read Ch. 32 for Thursday omit 32.3, 32.6, 32.9 (for now)
- Written Homework 31.45, 31.60, 31.70 (due next Thurs)
- Test #3 is 1 week from Thursday
  - Ch. 28, 29, 30, 31

Unidentified Clickers

- Baugh, Ben
- Burgess, Patrick
- Hammond, Joseph
- Holguin, Brandon
- Klotz, Cameron
- Ludi, Jordan
- Misla, Aaron
- Philips, Nicholas
- Reyes, Andres
- Woolridge, Ryan

DC Circuits I – Basic ideas

Current leaves + terminal of battery, passes through circuit and returns to – terminal.

Current does NOT get "used up"

Voltage drops (with respect to ground) as you move through the circuit.

Energy gets "used up" (the energy put out by the battery gets used in each of the "load" resistors.)

Light bulbs get brighter if you put more power through them. The power rating of a lightbulb tells you its resistance.

DC Circuits II – Kirchoff's Laws

Voltage drops sum to zero around any loop in a circuit

Sum of voltages across all series elements = battery voltage.

Voltages are same across all parallel elements.

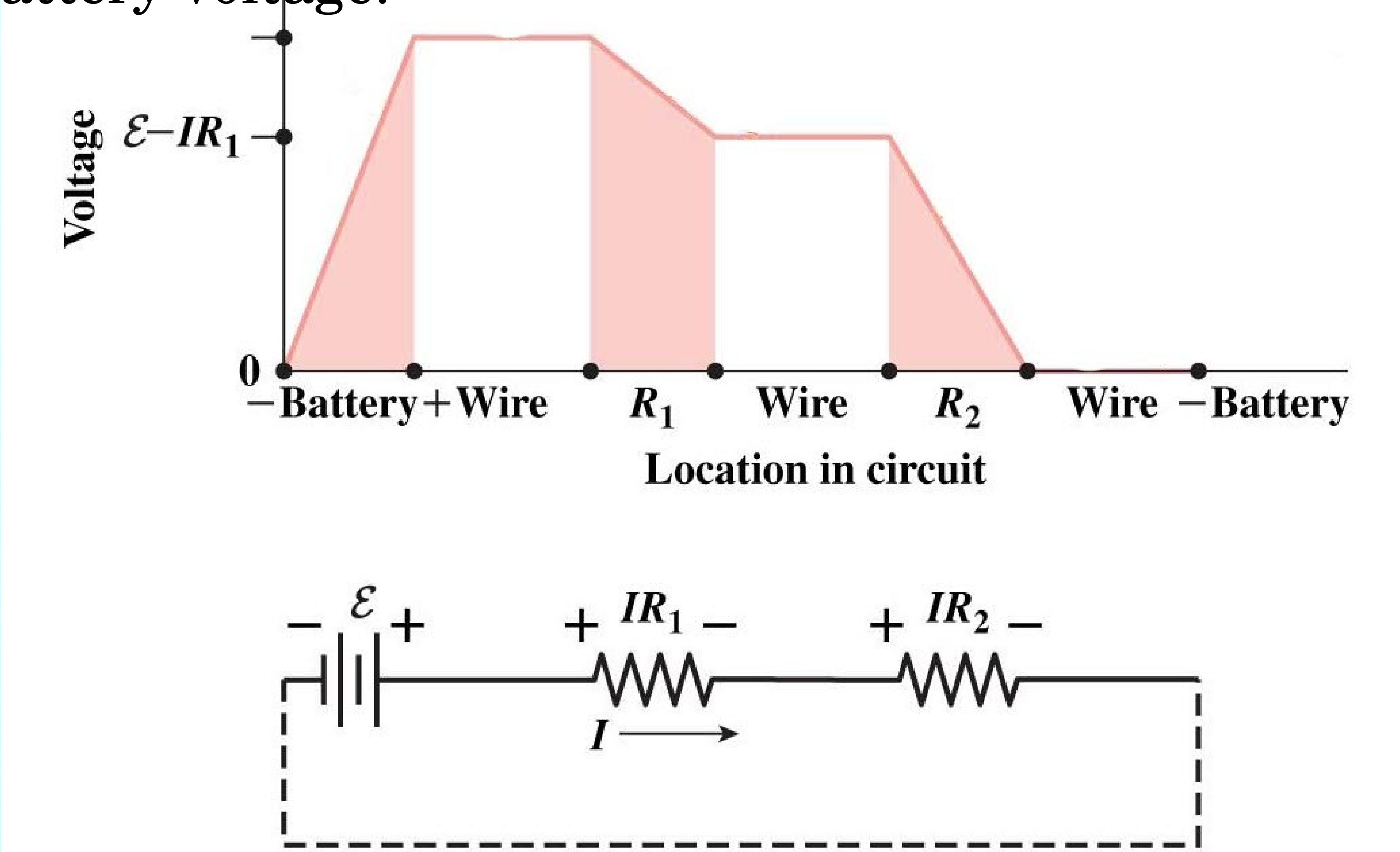
Current into a node is same as current out of a node

Current is the same in all series elements.

Current splits across parallel elements.

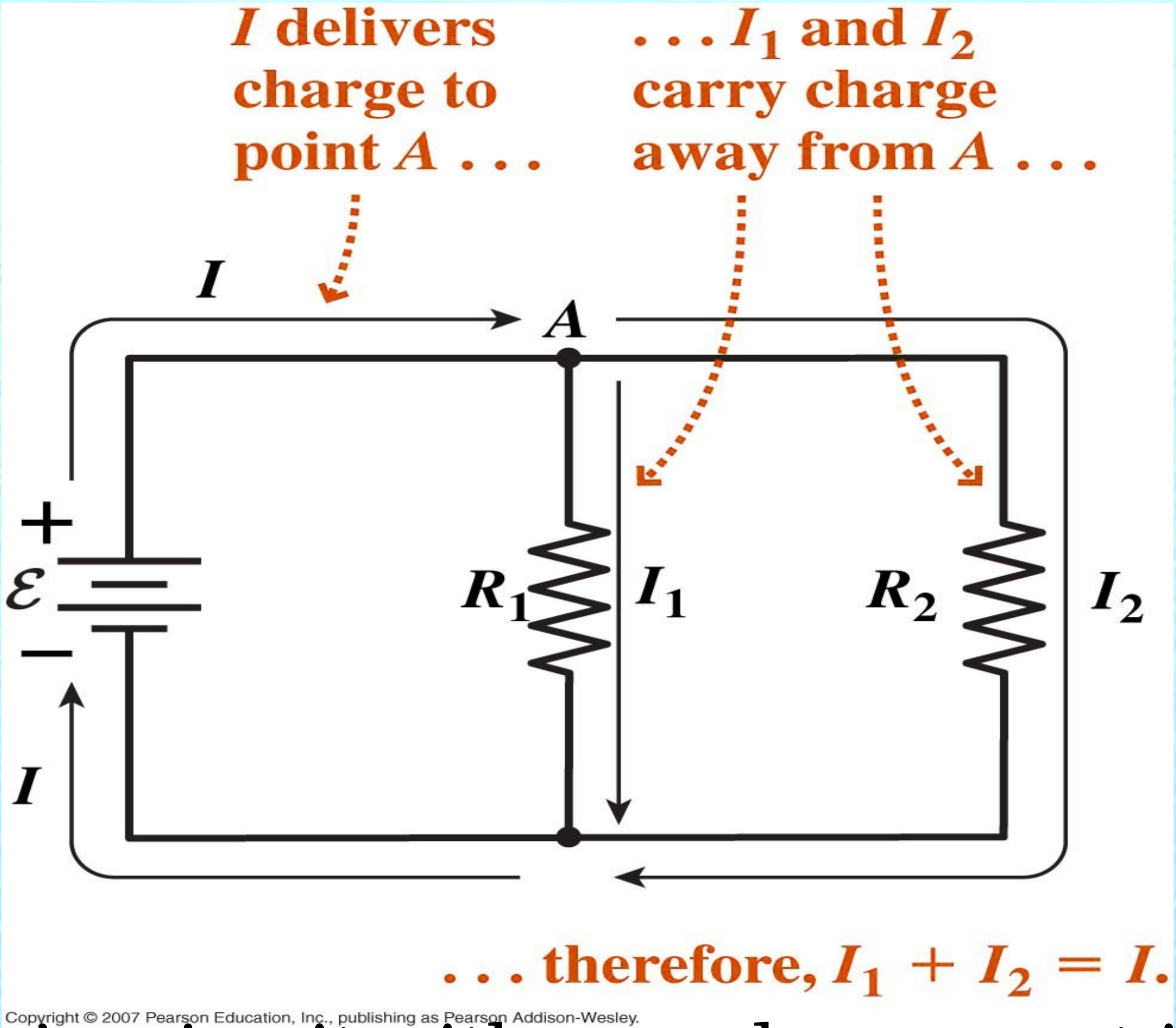
Kirchoff's Voltage Rule: (Loop rule)

- Sum of voltage drops around circuit (including battery) is zero.
- Sum of voltage drops across circuit element = battery voltage.



Kirchoff's Current Rule (Node rule):

Sum of currents entering any node is sum of currents leaving the node.



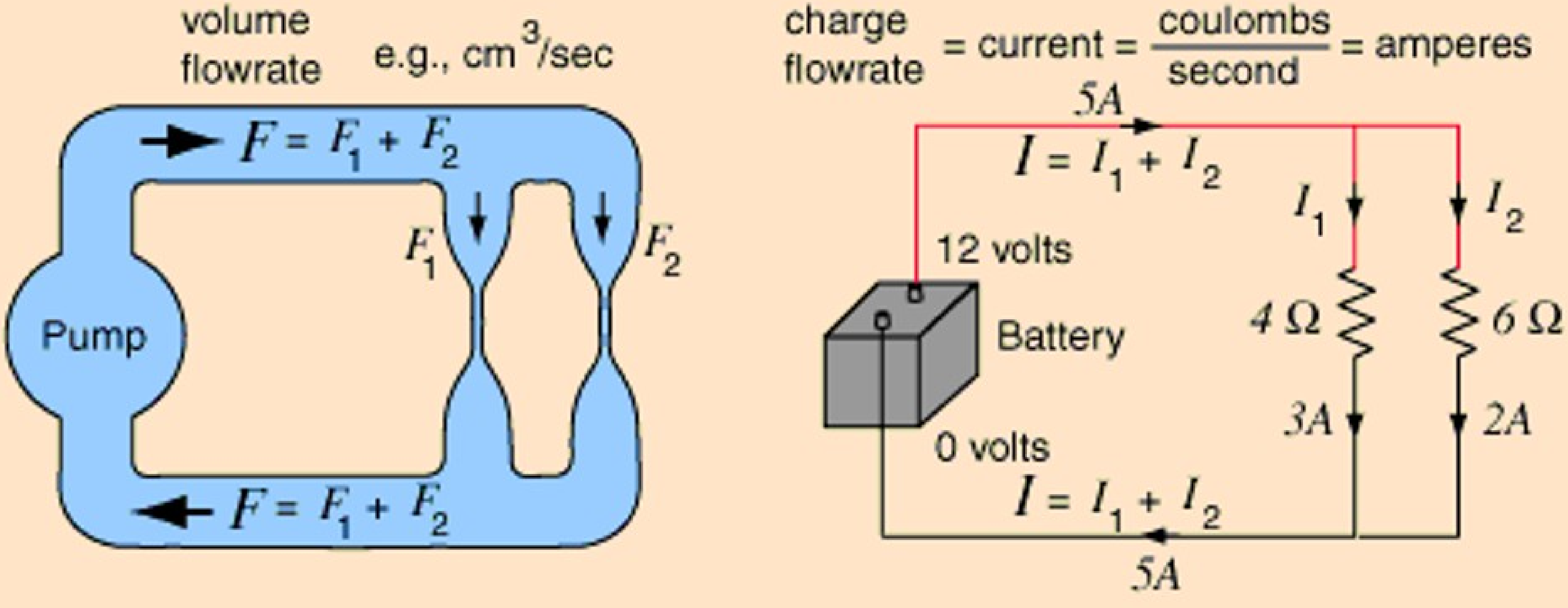
So in a series circuit with no nodes, current is same everywhere.

Parallel circuits:

Same voltage drop across resistors.

Current splits between resistors.

$$\frac{1}{R_{equivalent}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$



Properties of Equivalent Resistors

If you replace a circuit with its equivalent resistor then:

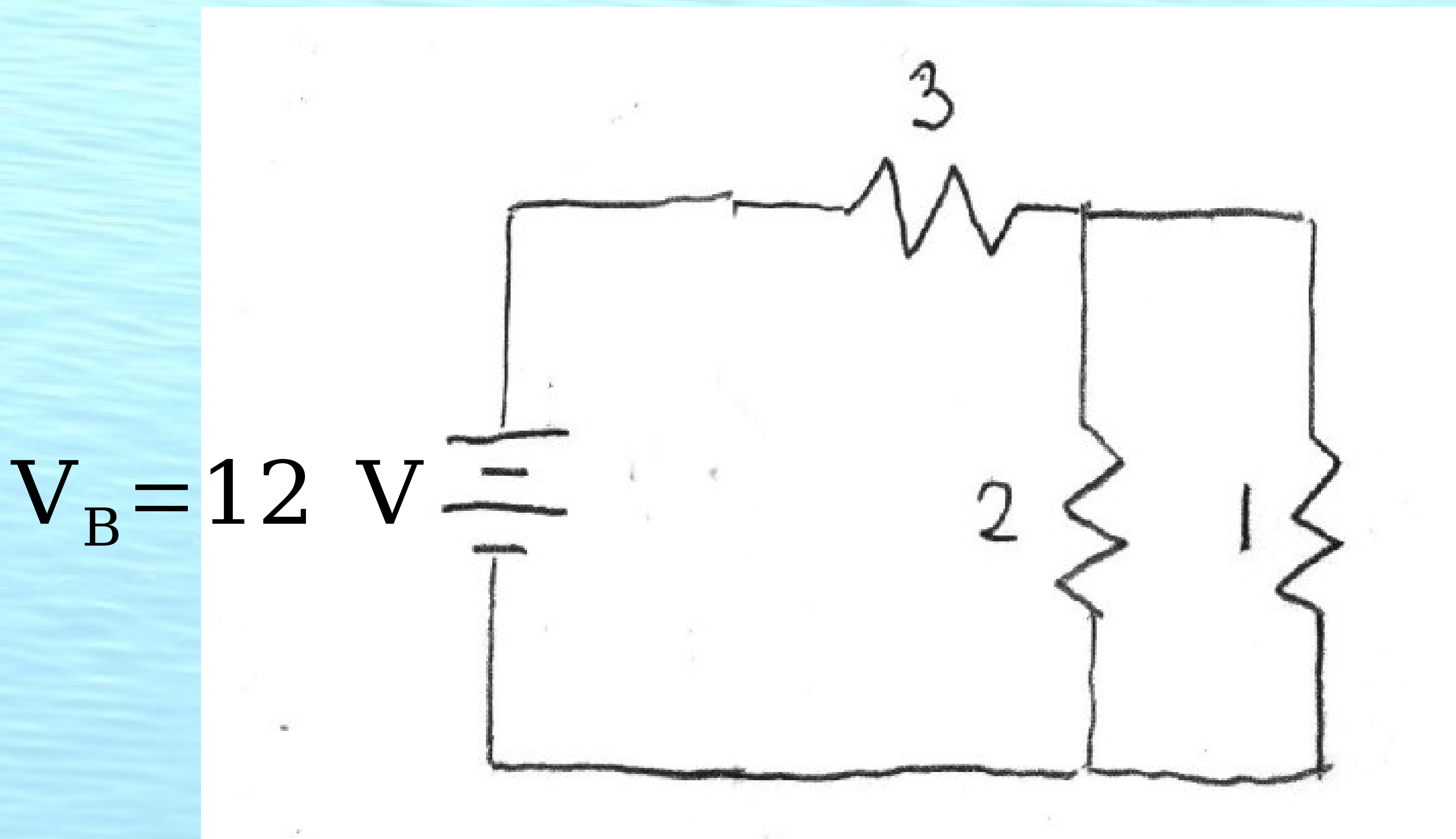
1) The current through the equivalent resistor is the same as the TOTAL current through the original circuit.

2) The power used by the equivalent resistor is the same as the TOTAL power used by the original circuit.

3) The sum of the power used at each original resistor equals the power used by the equivalent resistor.

4) The sum of the currents thru all parallel legs is the same as the current through the equivalent resistor.

What is the equivalent resistance of this circuit?
What is the voltage across the 2-Ohm resistor?
What is the voltage across the 3-Ohm resistor?



$R_{eq} = 3.66\,\Omega$ $I_{total} = 3.27\text{ A}$

$\Delta V_2 = 2.18\text{ V}$ $P_{total} = 39.3\text{ W}$

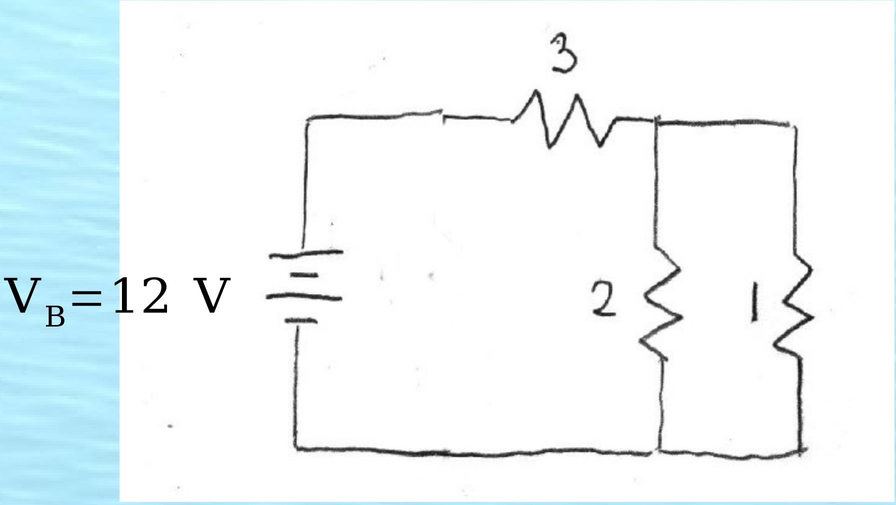
$\Delta V_3 = 9.81\text{ V}$

1) Current thru R_{eq} = current from battery.
2) Power thru R_{eq} = total power.
3) Sum of individual resistor powers = total power?
4) Sum of currents thru parallel legs = total current?

$P_3 = 32.1\text{ W}$

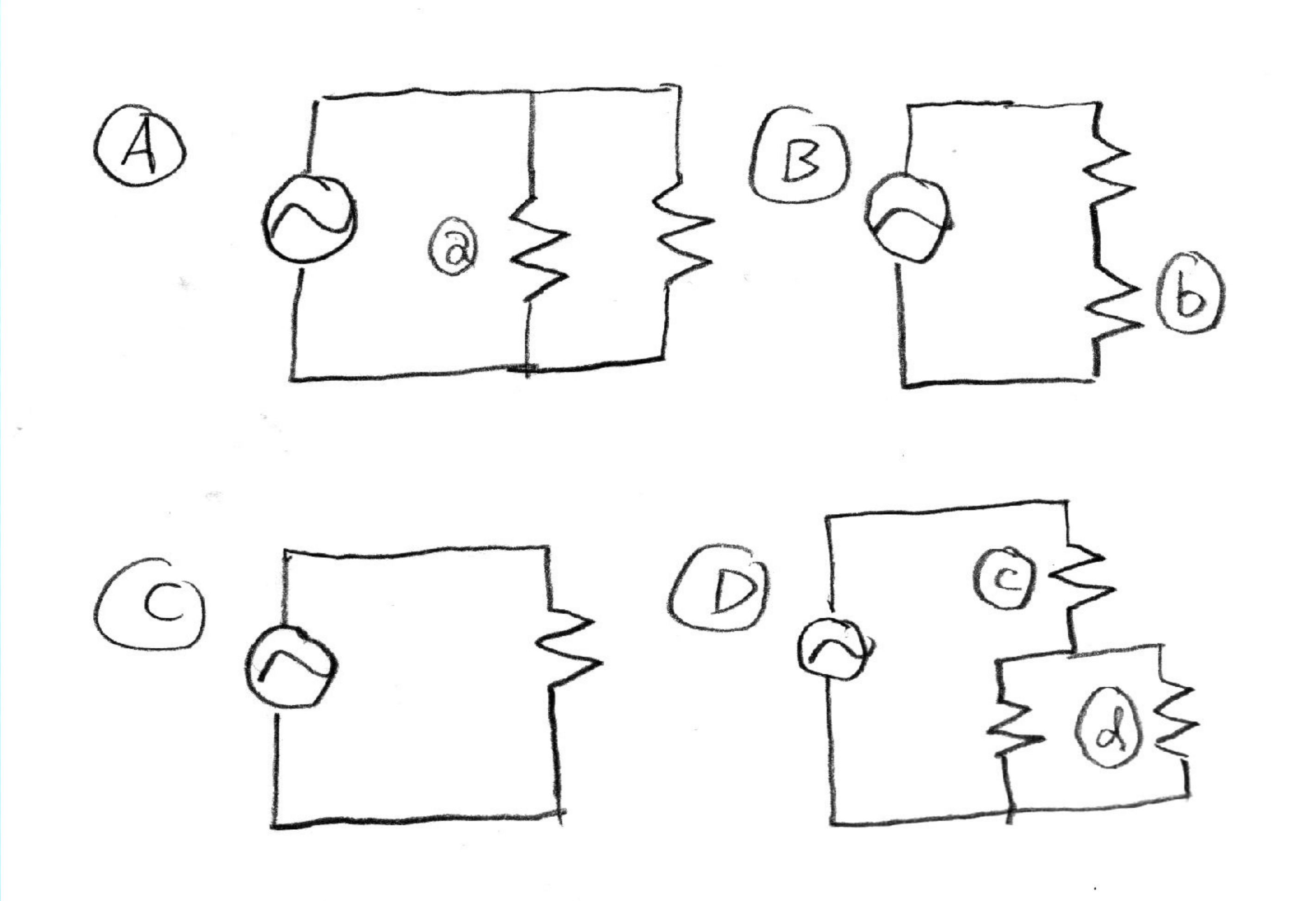
$P_1 = 4.75\text{ W}$

$P_2 = 2.38\text{ W}$



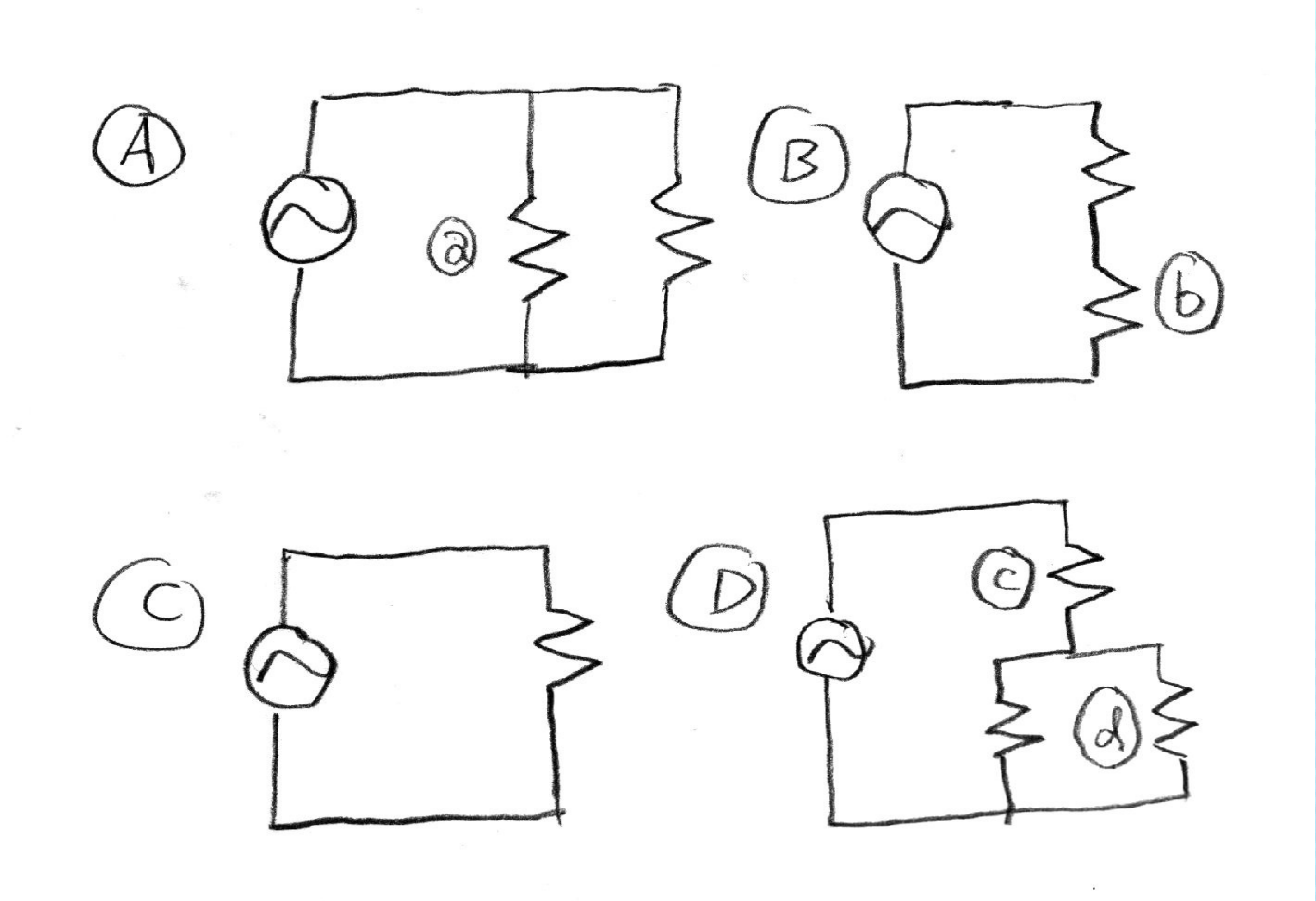
All of the resistors have the same value. Each of the power supplies is a constant voltage supply (and all are equal). Which circuit uses the most power?

(A) A
(B) B
(C) C
(D) D



All of the resistors have the same value. Each of the power supplies is a constant voltage supply (and all are equal). Which circuit uses the *least* power?

(A) A
(B) B
(C) C
(D) D



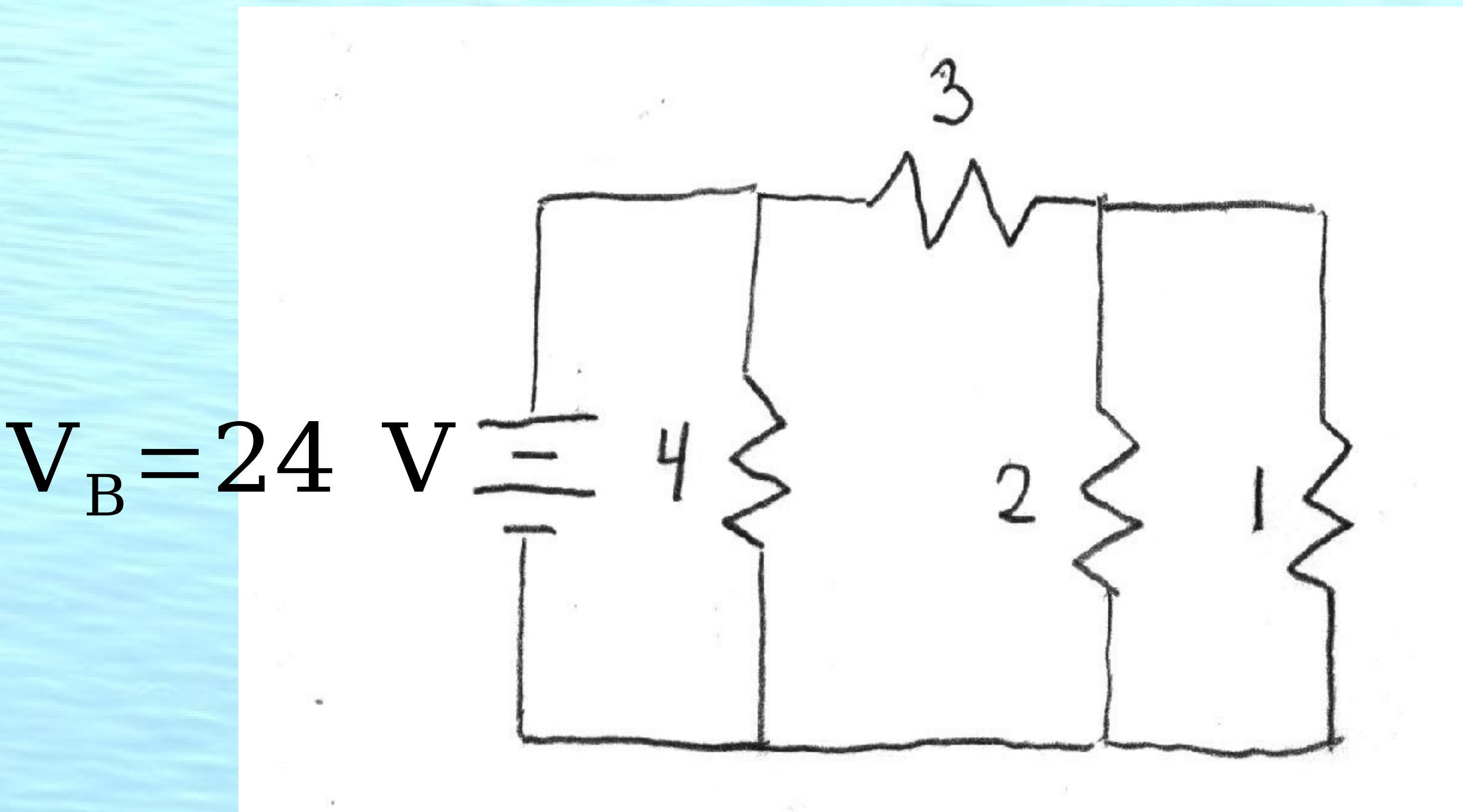
Clickers: You have a single 60-W light-bulb attached to an “ideal” battery.
You want to add
another 60-W bulb to make the room brighter. How should it be added?

[A] Put it in series with first bulb.
[B] Put in in parallel with first bulb.
[C] Both “A” and “B” will make the room brighter. (Brightness
set by Wattage of lightbulb)
[D] Neither “A” or “B” will help – the battery puts out constant power.

What is the equivalent resistance of this circuit?

What is the voltage across the 2-Ohm resistor?

What is the voltage across the 3-Ohm resistor?

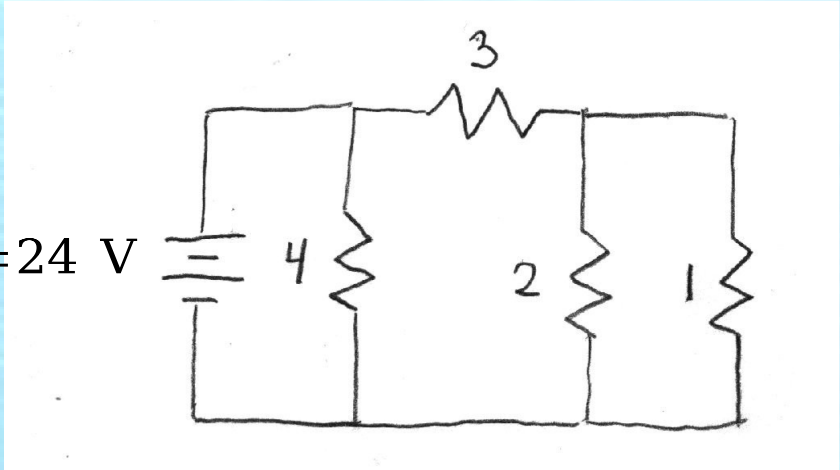


$R_{eq} = ?...$

$\Delta V_2 = ?...$

$\Delta V_3 = ?...$

$V_B = 24\ V$



Redraw this circuit to show parallel/series combos better.
Given V = 11 Volts. Example of Kirchhoff's Voltage law.

$$I_4 = \frac{11}{4} \text{ A} \qquad R_{eqv_{12}} = \frac{2}{3} \ \Omega \qquad R_{eqv_{123}} = \frac{11}{3} \ \Omega$$

$$I_3 = 3 \text{ A}$$

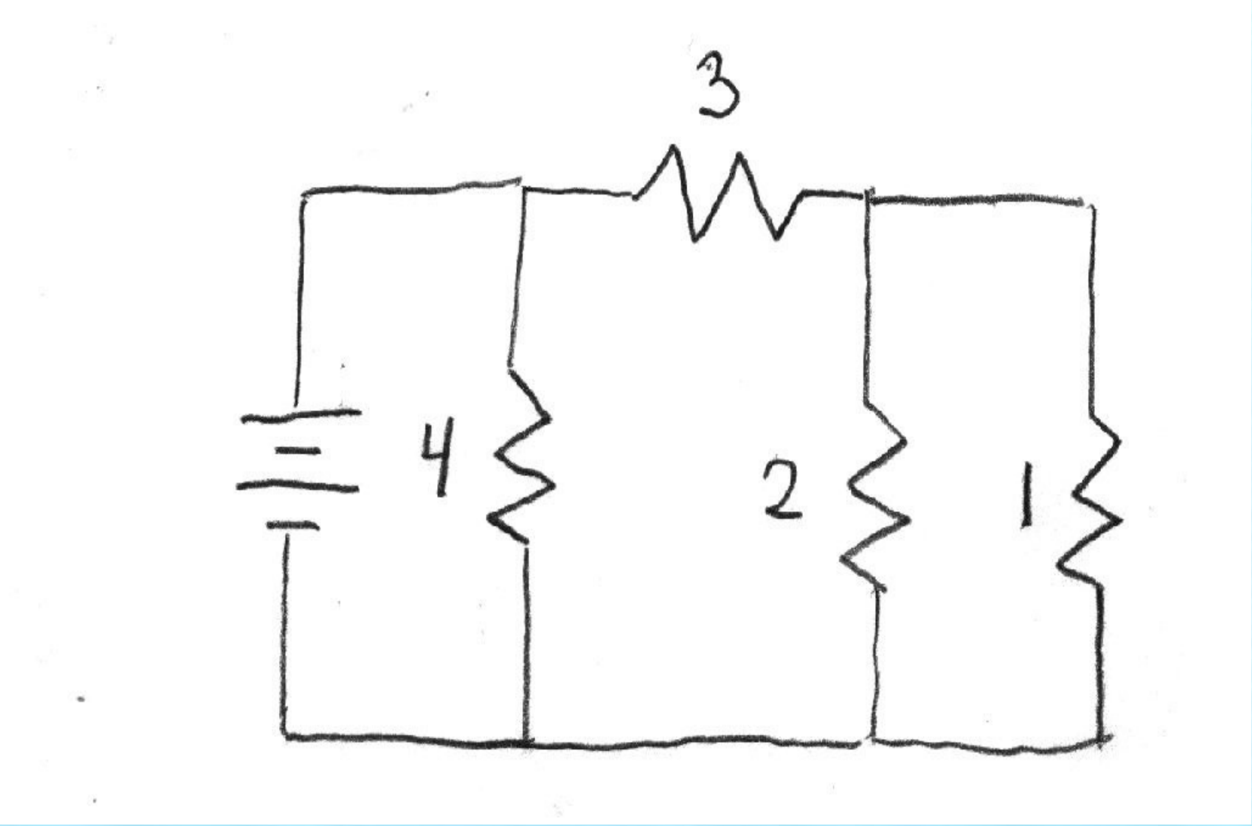
$$I_1 = 2 \text{ A}$$

$$I_2 = 1 \text{ A}$$

$$V_3 = 9 \text{ V}$$

$$I_{total} = 5.75 \text{ A}$$

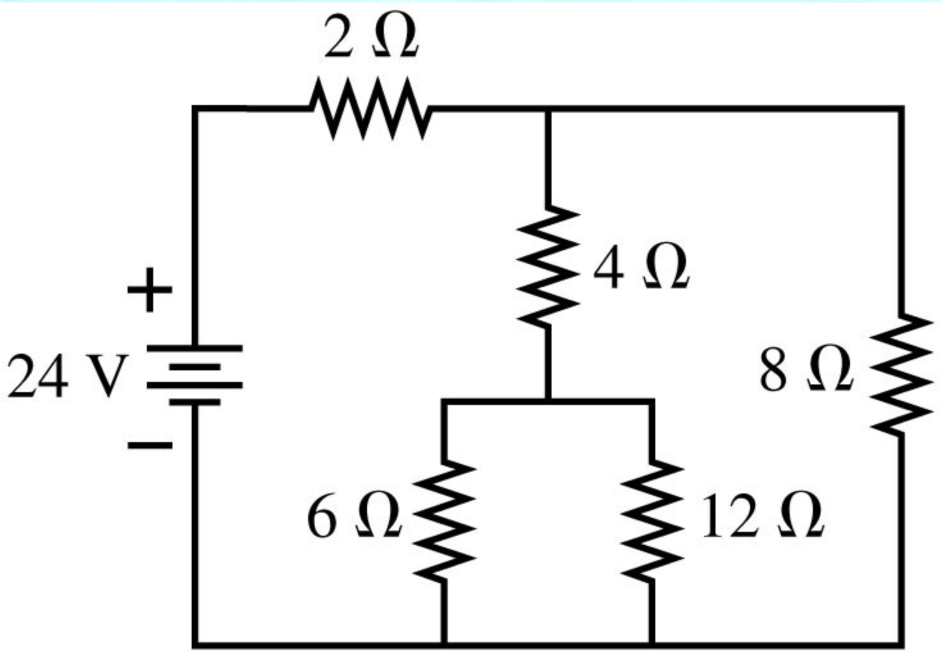
$$R_{eqv_{total}} = \frac{44}{23} \ \Omega$$



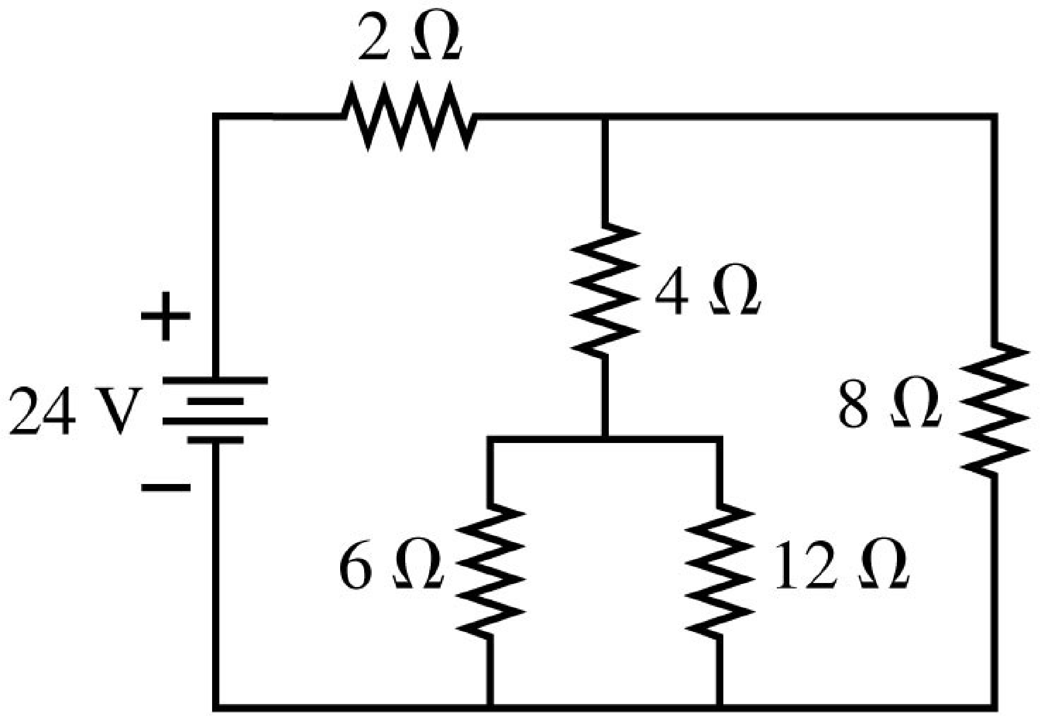
Solving resistor network problems

1) Redraw the circuit as needed to see what parts are in series and what parts are in parallel.
2) Replace each section with an equivalent resistor for that section.
3) Combine equivalent resistors to get down to a single resistor. Get total current.
4) Apply current to all series sections to get voltage drop.
5) Apply voltage drop to all parallel sections to get current.

Problem 31.60 – Find current thru and voltage across each resistor.

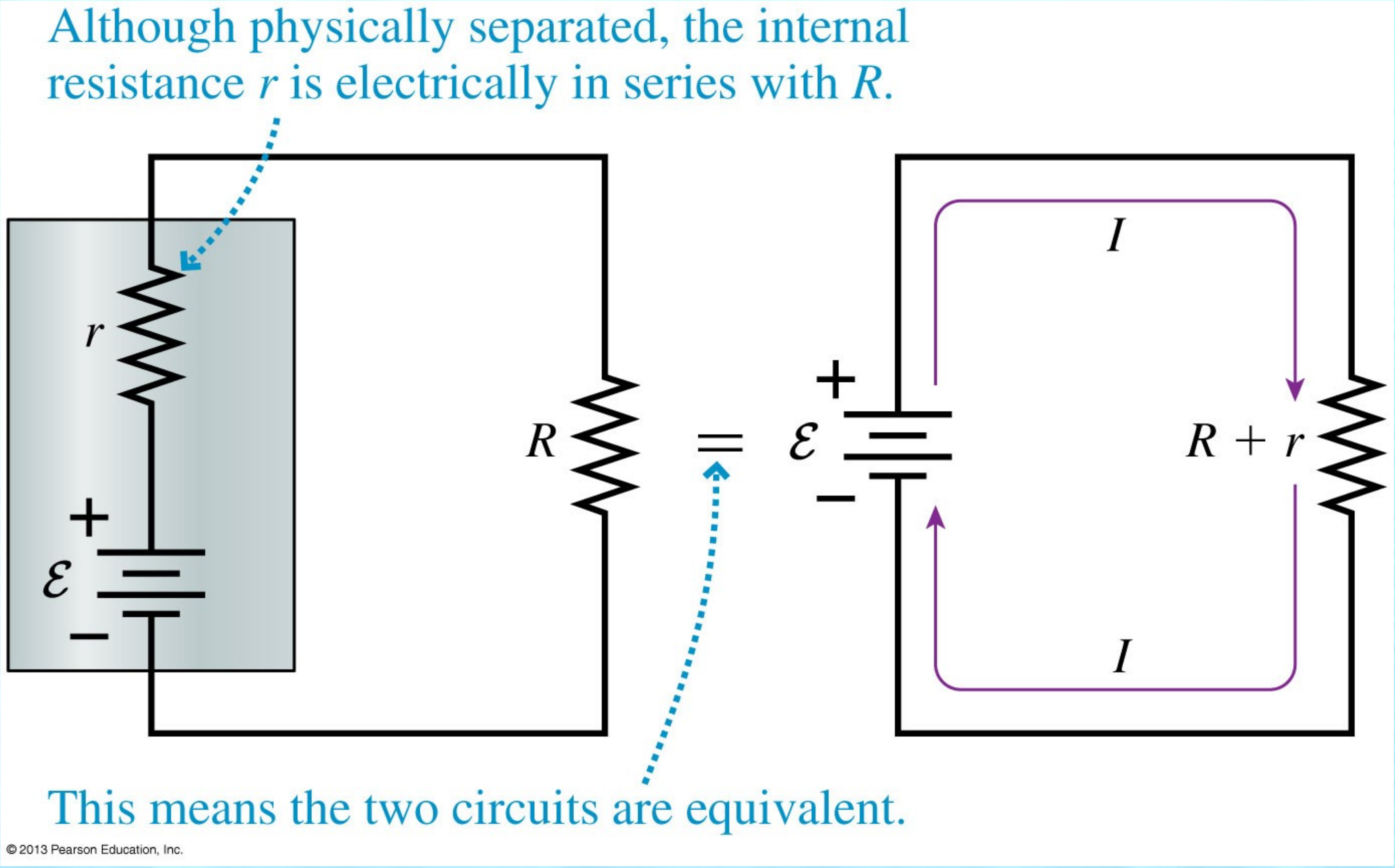


Problem 31.60



Can you start a car with 8 AAA batteries in series?

Ideal battery vs. Real battery



Calculating internal resistance.

You measure your car battery and find it to read 13 Volts "open circuit"

You measure the voltage while starting your car and see that it is only 10 Volts. You know that your starter motor requires 500 Amperes. What is the internal resistance of your car battery?

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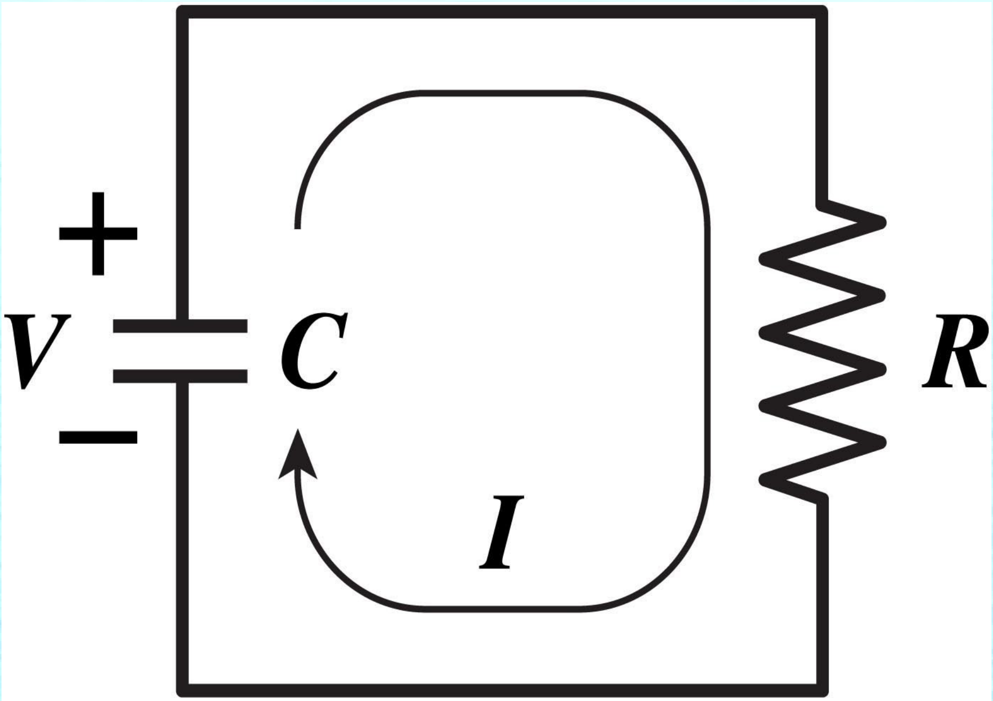
RC Circuits

A circuit with both a resistor and a capacitor in it is called an “RC-circuit”.

A circuit of pure resistors comes to equilibrium in less than a picosecond.

RC circuits have a characteristic time $\left(\tau = RC\right)$ Before they reach equilibrium.



$$Q_C = Q_0 e^{-t/RC}$$

If capacitor begins charged ---> $$V_C = V_0 e^{-t/RC}$$

$$I = I_0 e^{-t/RC}$$

Is an Ohm Farad really a second?

$$Q = CV \rightarrow C = \frac{Q}{V} \rightarrow [\text{Farad}] = \frac{[\text{Coul}]}{[\text{Volt}]}$$

$$V = IR \rightarrow R = \frac{V}{I} \rightarrow [\text{Ohm}] = \frac{[\text{Volt}]}{[\text{Amp}]}$$

$$RC = [\text{Ohm}][\text{Farad}] = \frac{[\text{Volt}]}{[\text{Amp}]} \times \frac{[\text{Coul}]}{[\text{Volt}]}$$

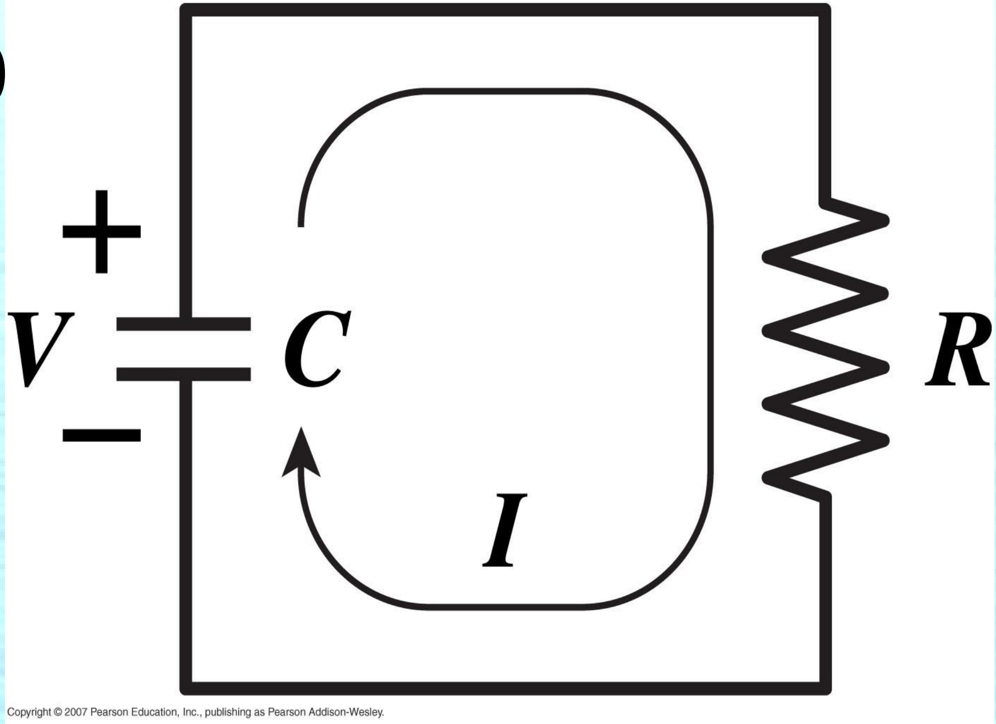
$$RC = \frac{[\text{Coulomb}]}{[\text{Amp}]} = \frac{[\text{Coul}]}{[\text{Coul/second}]} = \text{seconds!}$$ ¿

RC Circuits Demo (RC_time_constant1.avi)

$$C = 0.5\ [\text{Farad}], \tau = 0.3\,\text{sec}, R = ?$$

If capacitor begins charged ...

$$V + IR = 0 \rightarrow \frac{Q}{C} + \frac{dQ}{dt}R = 0$$



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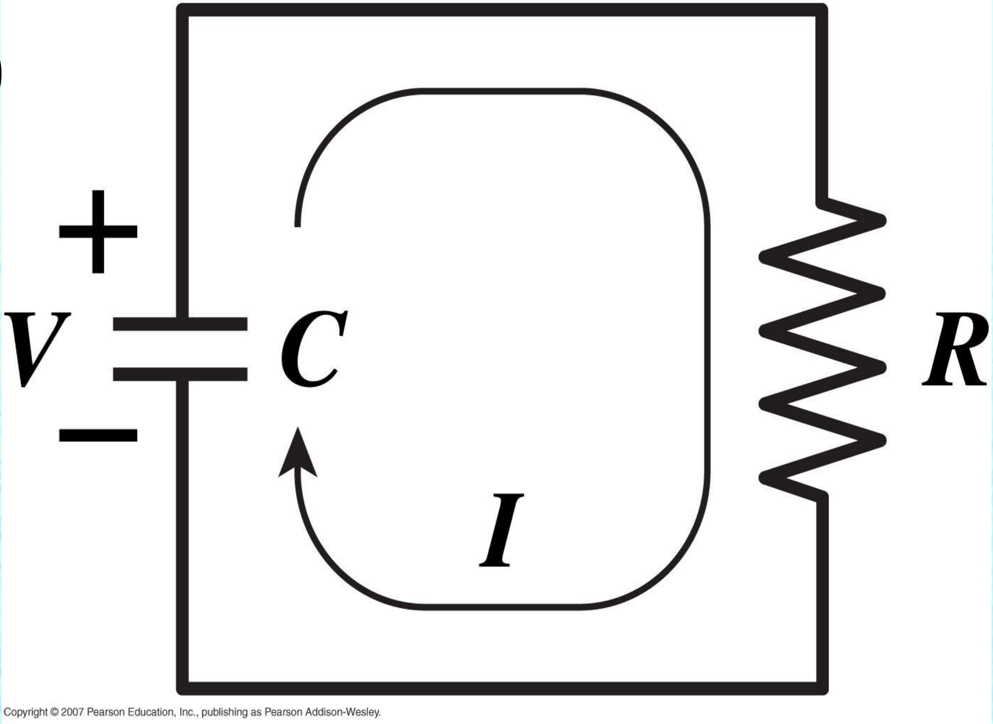


$$\frac{dQ}{dt} = -\frac{Q}{RC}$$

$$\frac{dQ}{Q} = -\frac{dt}{RC}$$

$$\int \frac{dQ}{Q} = -\frac{1}{RC}\int dt$$

$$\ln Q = -\frac{t}{RC} + \kappa$$

$$Q = e^{-t/RC} e^{\kappa}$$

$$Q = Q_0 e^{-t/RC}$$

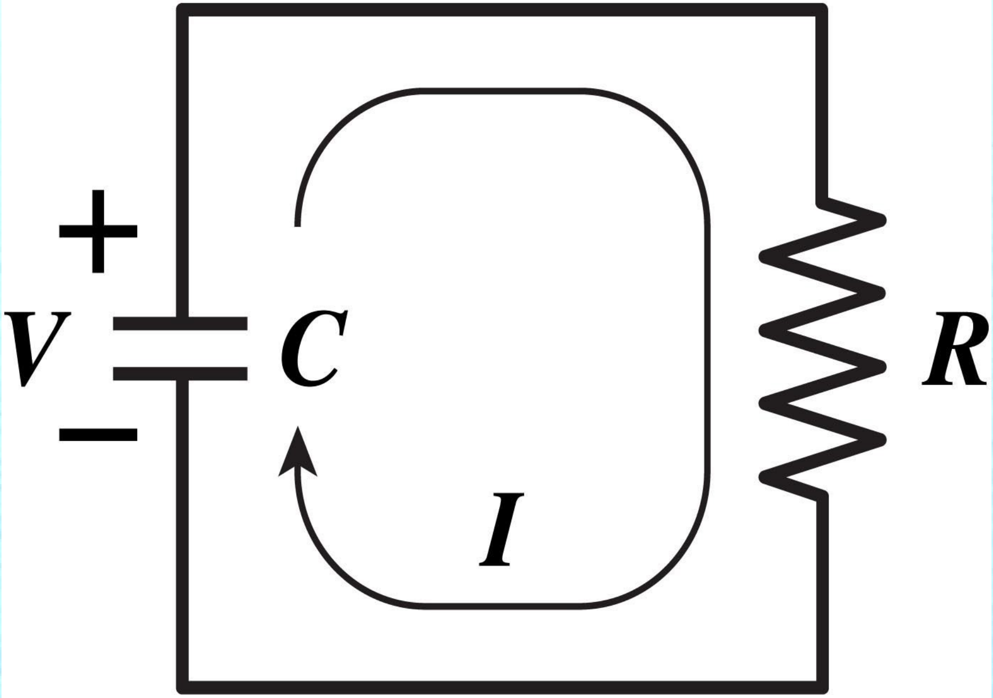
$$V_C = \frac{Q_0}{C} e^{-t/RC}$$

If capacitor begins charged ...

$$\frac{dQ}{dt} = -\frac{Q}{RC}$$

$$Q = Q_0 e^{-t/RC}$$

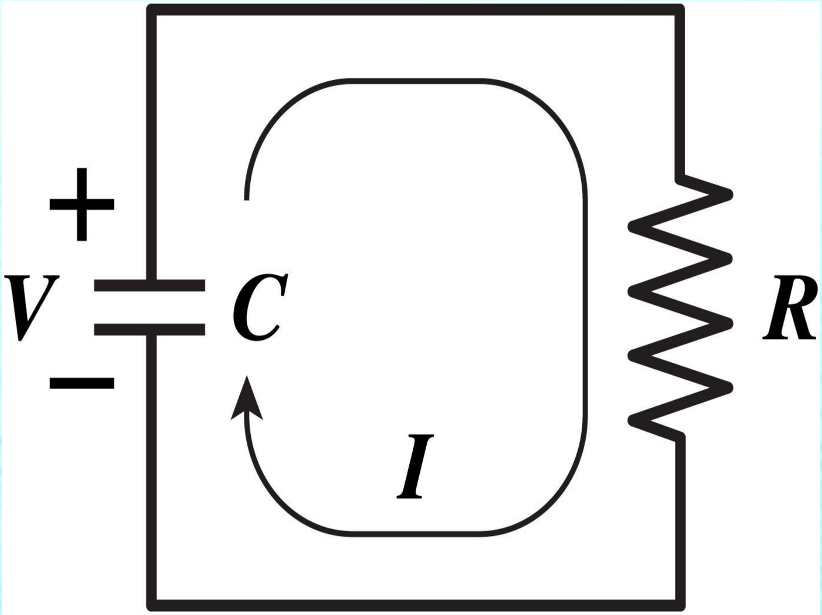
What is I(t)?



Given $Q(t) = Q_0 e^{-t/RC}$

And $I(t) = \dfrac{-dQ}{dt}$

What is $I(t)$?



[A] $Q_0 e^{-t/RC}$

[B] $Q_0 RC e^{-t/RC}$

[C] $-Q_0 RC e^{-t/RC}$

[D] $\dfrac{1}{RC} e^{-t/RC}$

[E] $\dfrac{Q_0}{RC} e^{-t/RC}$

RC Circuits

RC circuits have a characteristic time $(\tau = RC)$ Before they reach equilibrium. Note that R and C never appear alone

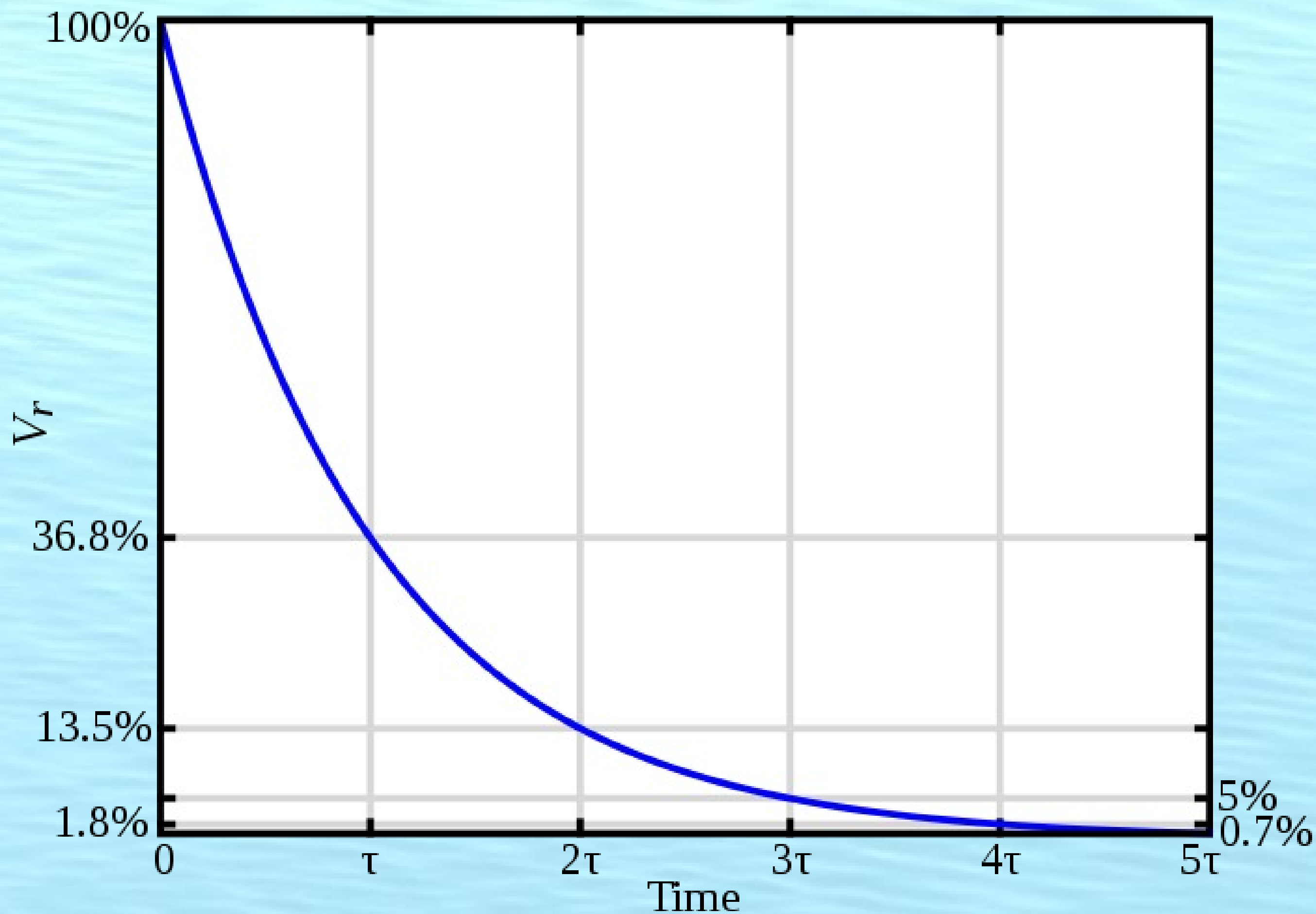
$$Q = Q_0 e^{-t/RC}$$

$$I = I_0 e^{-t/RC}$$

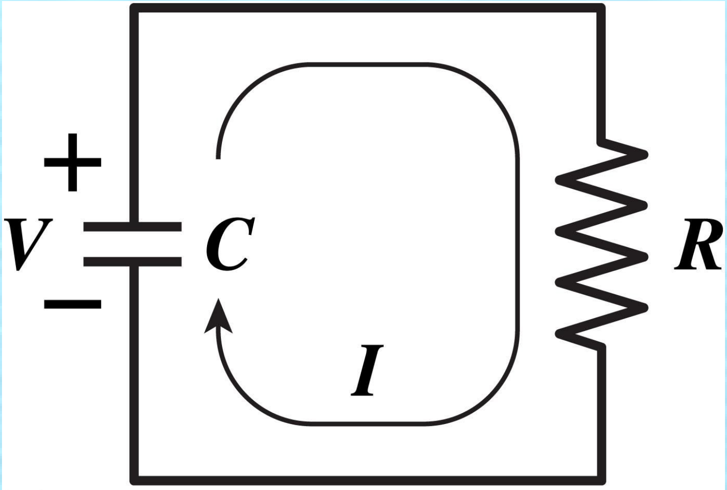
$$I = -\frac{Q_0}{RC} e^{-t/RC}$$

$$V_C = V_0 e^{-t/RC}$$

$$V_C = \frac{Q_0}{C} e^{-t/RC}$$



A 200 kΩ resistor is in series with C=10 μF. A t=0, the voltage on the capacitor is 8 V. What is the voltage on the capacitor and the current through the resistor after 1 sec, 2 sec and 4 seconds?



A 200 kΩ resistor is in series with $C=10\,\mu F$.
A t=0, the voltage on the capacitor is 8 V.
What is the voltage on the capacitor and the current through the resistor after 1 sec, 2 sec and 4 seconds?

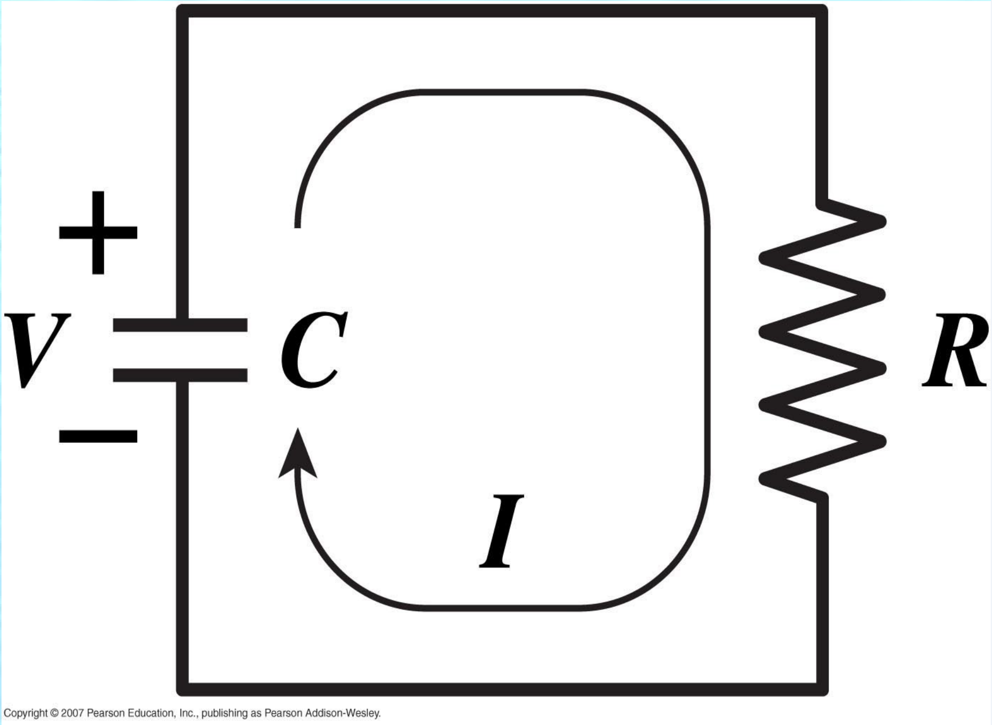
$$I=I_0 e^{-t/RC} \qquad I=\frac{V_0}{R}e^{-t/RC}$$

$$V=V_0 e^{-t/RC}$$

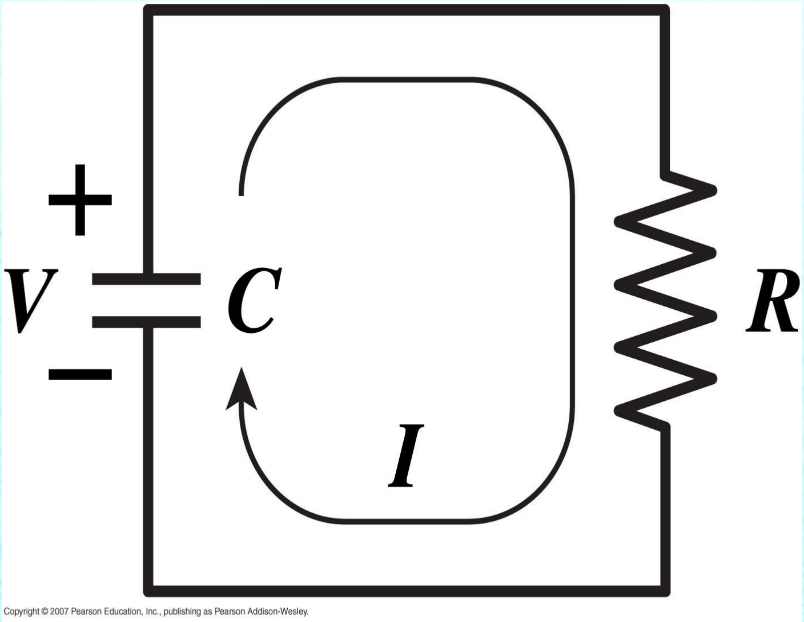
$$RC=(2.0\times10^{5}\,\Omega)(1.0\times10^{-5}\,F)$$

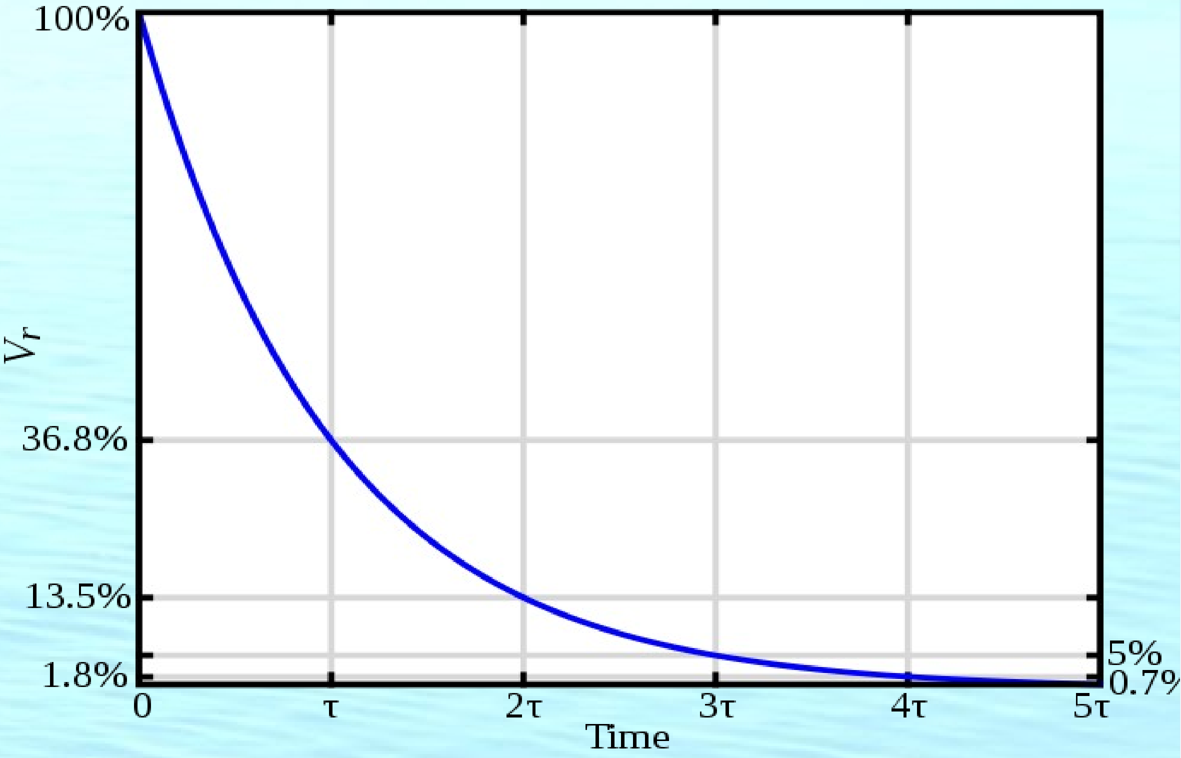
$$V(4)=8e^{-4.00s/2.00s}\ \text{Volts}$$

$$V(4)=8\times0.135=1.08\ \text{Volts}$$



Time for pHeT (AC Circuits Lab)





In this circuit, where capacitor begins charged --->

$$V_C = V_0 e^{-t/RC}$$

$$I = I_0 e^{-t/RC}$$

Find the resistance needed in an RC circuit to discharge a 20 μF capacitor to 55% of full charge in 140 ms.

Find the resistance needed in an RC circuit to discharge a $20\ \mu F$ capacitor to 55% of full charge in 140 ms.

$$Q_C = Q_0 e^{-t/RC}$$

$$0.55\,Q_0 = Q_0 e^{-t/RC}$$

$$0.55 = e^{-t/RC}$$

$$\ln(0.55) = \ln\left(e^{-t/RC}\right)$$

$$-0.597 = \frac{-t}{RC}$$

$$R = \frac{t}{0.597C}$$

$$R = \frac{1.40\times10^{-1}\ s}{0.597\cdot2.0\times10^{-5}\ F}$$

$$R = 11.74\ k\Omega$$