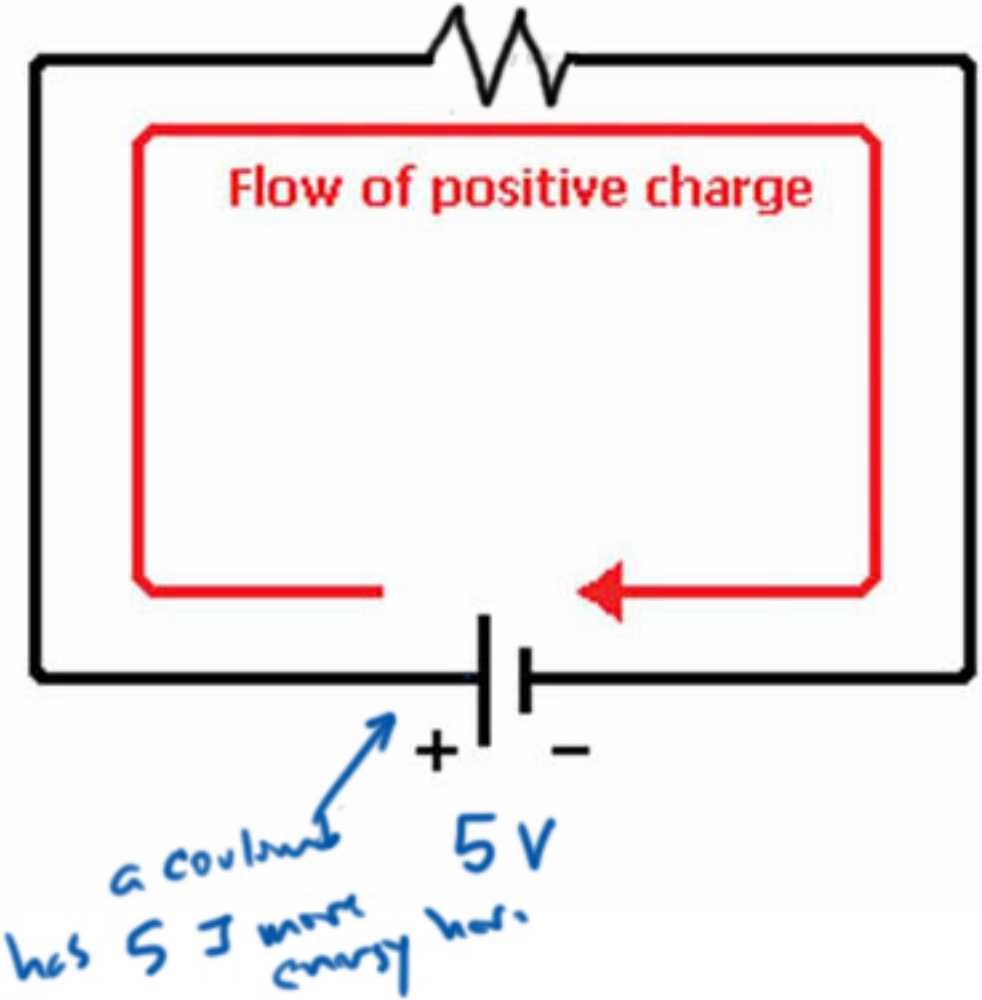
Module 11

DC Current

Session Slides with Notes

DC Current

- current (I)
  - ampere
  - $1\,A = C/s$
- voltage (V)
  - $1\,V = J/C$
- resistance (Ω)

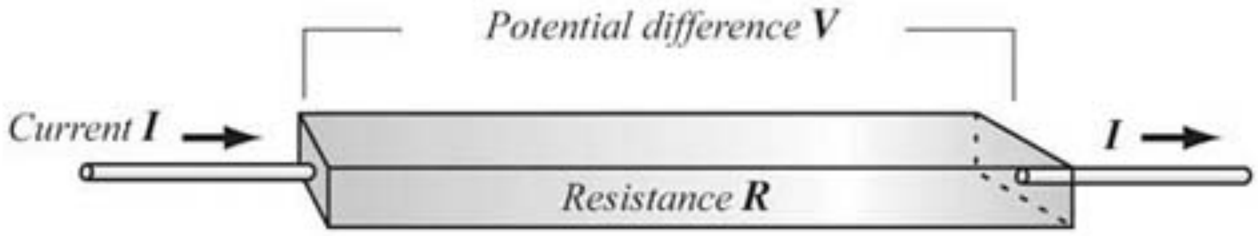


Ohm's Law

$$V = IR$$

$$I = \frac{V}{R}$$

V = electric potential
I = current
R = resistance



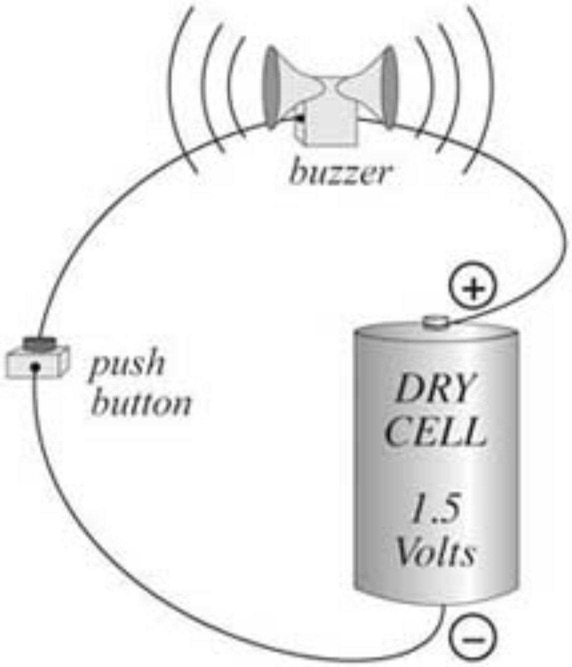
When the push button at right is depressed, the 1.5 V battery causes the 50 Ω buzzer to sound. What current flows through the circuit?

a. 15 mA

b. 30 mA

c. 75 A

d. 150 A



$V = IR$

$I = V/R$

$= \frac{1.5\ V}{50\ \Omega}$

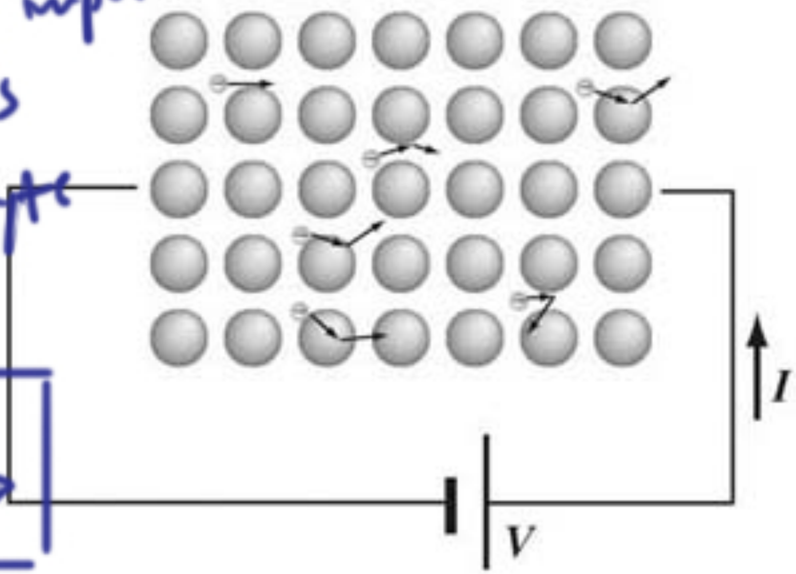
Resistance of a Uniform Conductor

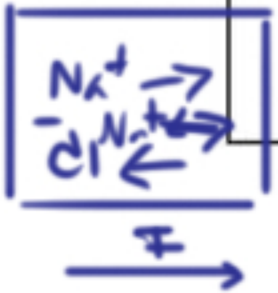
$$\rho = \frac{1}{\sigma}$$

↑ conductivity especially important for solutions of electrolyte

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

R	=	resistance
L	=	resistor length
A	=	resistor cross-sectional area
σ	=	conductivity
ρ	=	resistivity ($1/\sigma$)





By convention, the direction of current is expressed as the flow of positive charge, which is opposite the direction of electron flow in a metallic conductor.

Metal conductors

- Resistance increases with T

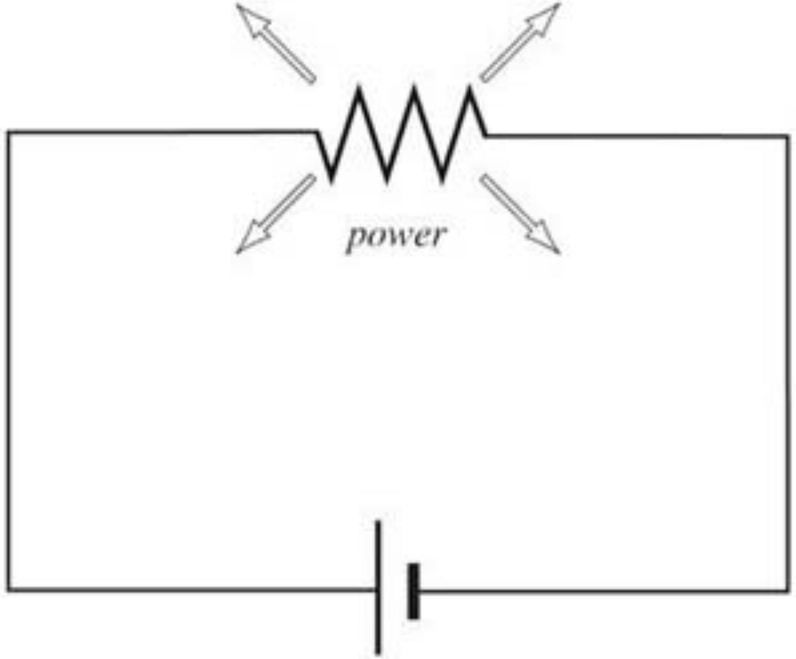
Semiconductors

- Resistance decreases with T

Electric Power

$$P = IV = I^2R = \frac{V^2}{R}$$

P = power
I = current
V = potential
R = resistance

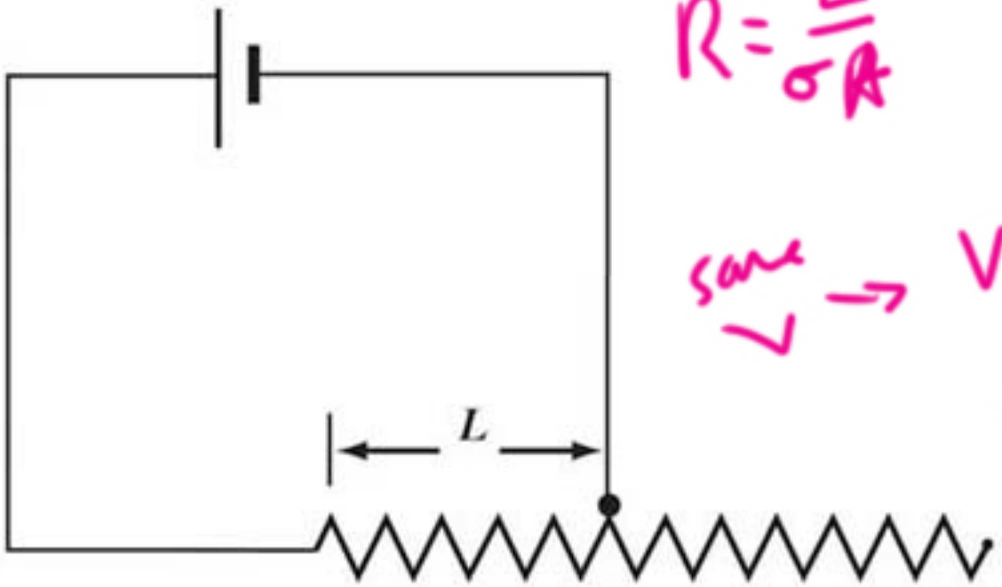


$P = IV$

$(J/s) = (C/s)(J/C)$

$1\ J/s = 1$ watt

With neglible internal resistance, a battery delivers a steady voltage to a variable resistor. With P_i representing the initial power output, what is the final power of the circuit when the length of the variable resistor is halved?



$R = \frac{L}{\sigma A}$ $\frac{1}{2}L \Rightarrow \frac{1}{2}R$

same V → $V = IR$

twice the current

a. $\frac{P_i}{4}$ b. $\frac{P_i}{\sqrt{2}}$ c. $2P_i$ d. $4P_i$

A 10V battery delivers current to a resistor immersed in 100g water within a Dewar flask. What is the approximate current if the temperature of the water rises by one degree celsius ($1^{\circ}C$) per second?

$c = 1\, cal/g^{\circ}C$

$P = 100\, cal/s$

$1\, cal = 4.18\, J$

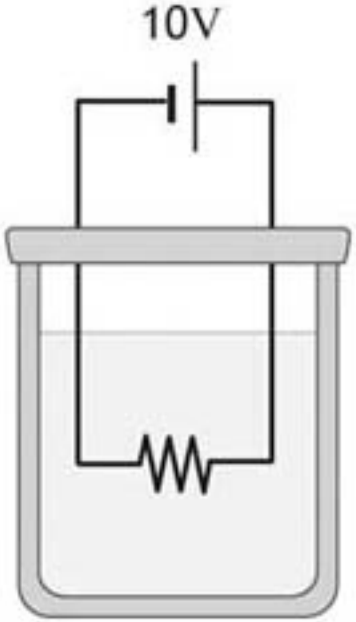
$= 400\, J/s$

a. 1 A

b. 2.5 A

c. 10 A

d. 40A



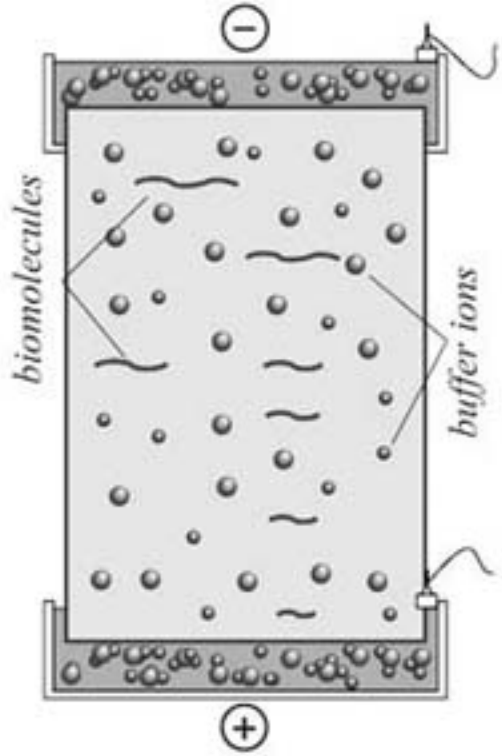
The varying mobility of biomolecules impelled by an electric field to migrate through a gel matrix enables their separation in gel electrophoresis. A buffered electrolyte solution provides the majority of electrical conductivity to the matrix. If a researcher inadvertently used a buffer solution of half normal concentration with the power supply set to its normal rate of constant current, which of the following would occur? *(Biomolecule charge-to-mass ratio unaffected).*

a. Slower migration of biomolecules

b. Increased apparatus temperature

c. Unchanged electrical parameters

d. Decreased electric field strength



$V = Ed$

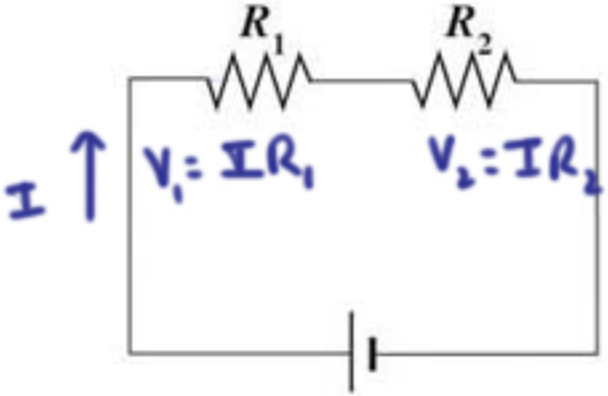
Resistance has increased!

Current stayed same.

Voltage increases.

Power increased

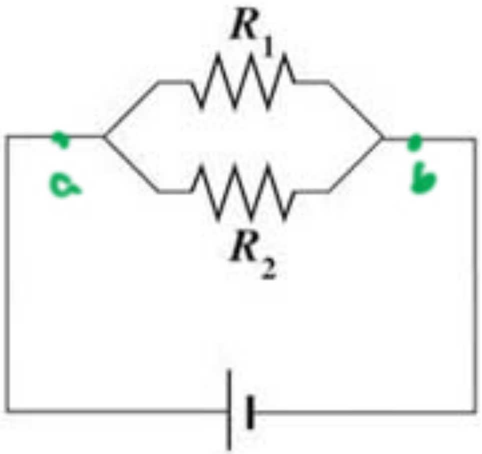
Equivalent Resistance of Series or Parallel Resistors



- current is the same through series resistors
- voltage drops as you go

$$R_{ser} = R_1 + R_2 + R_3 + \cdots$$

The equivalent resistance of resistors in series is greater than the resistance of any individual resistor in the series.



- voltage is the same across parallel resistors
- current follows the path of least resistance.

$$\frac{1}{R_{par}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

$$\frac{1}{R_{par}} = \frac{1}{R_1} + \frac{1}{R_2}$$

The equivalent resistance of resistors in parallel is less than the resistance of any individual resistor in parallel.

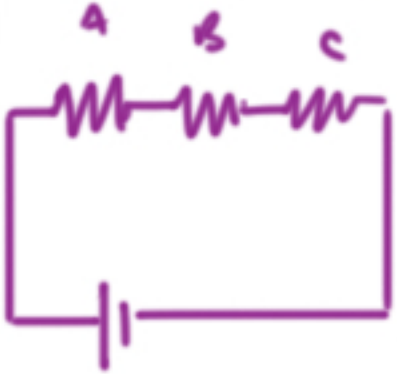
$$R_{par} = \frac{R_1 R_2}{R_1 + R_2}$$

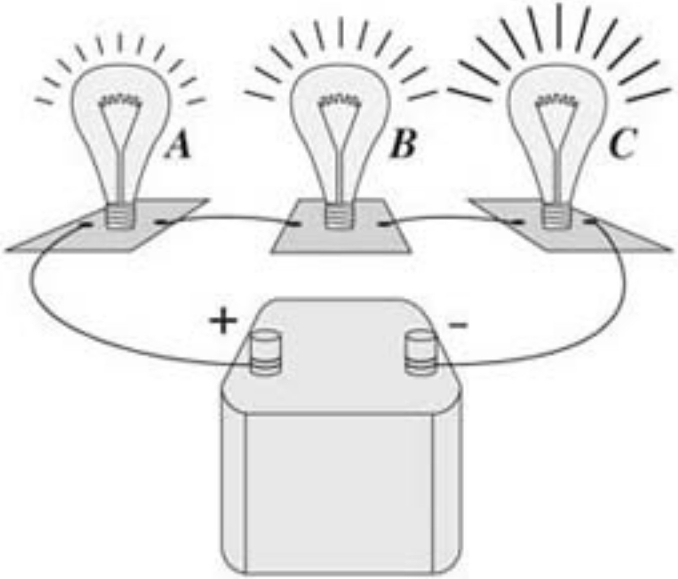
When three light bulbs of different wattage are attached in series to a steady DC power source, the order of brightness is $C > B > A$. If the circuit is then reconfigured so that the three bulbs are arranged in parallel, what would be the order of brightness in the new configuration?

$P_C > P_B > P_A$

$V_C > V_B > V_A$

$R_C > R_B > R_A$





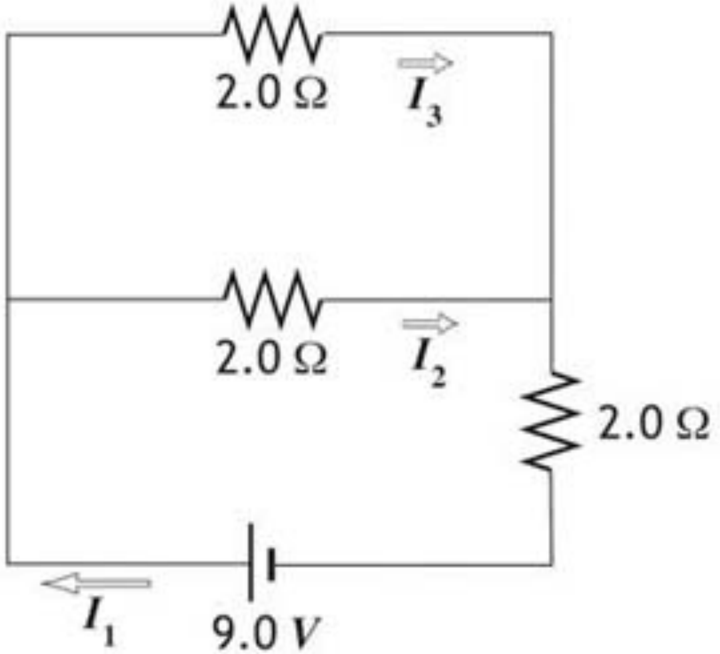
a. $A > B > C$

b. $B > A > C$

c. $C > B > A$

d. $A = B = C$

What is the value of the primary current, I_1?



$R_{pw} = 1\,\Omega$

a. 1.5 A

b. 2.25 A

c. 3.0 A

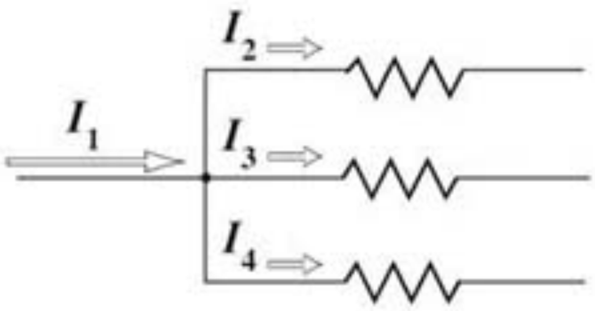
d. 4.5 A

Kirchhoff's Rules

Kirchhoff's First Rule (Branch Theorem)

$$I_1 = I_2 + I_3 + I_4$$

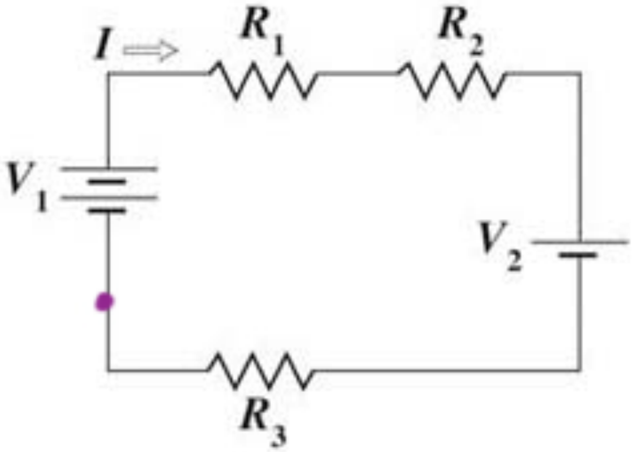
The sum of the currents into a junction equals the sum of currents out of the junction.



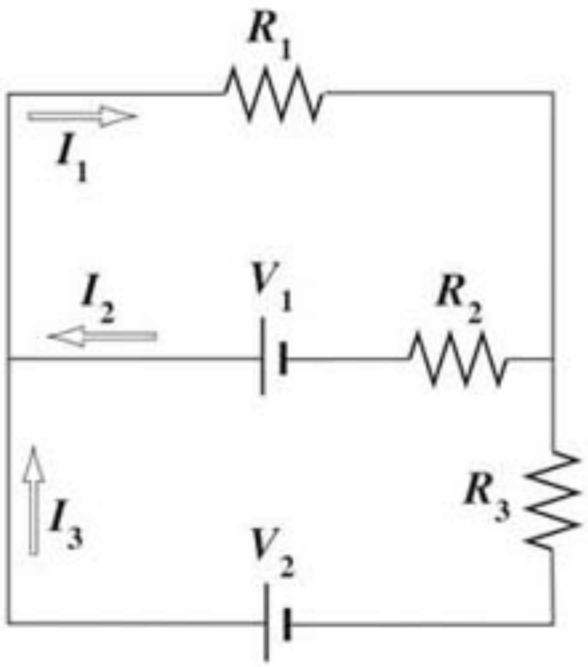
Kirchhoff's Second Rule (Loop Theorem)

$$V_1 - IR_1 - IR_2 - V_2 - IR_3 = 0$$

The sum of the changes in potential around any closed path is zero.



Which of the following statements validly describes the circuit at right?



I. $V_1 - I_1R_1 - I_2R_2 = 0$

II. $V_1 - V_2 + I_3R_3 - I_2R_2 = 0$

III. $I_1 = I_2 + I_3$

IV. $V_2 - I_1R_1 - I_3R_3 = 0$

a. I only

b. I and II

c. I, II and III

d. I, II, III, and IV

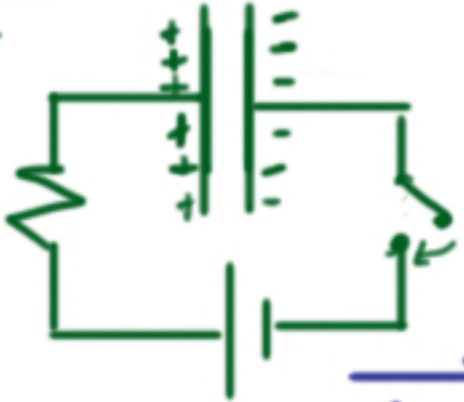
Capacitance

A capacitor with a high capacitance can hold a large amount of charge without requiring a high voltage.

$$C = \frac{Q}{V}$$

C = capacitance
Q = electric charge on a single plate
V = voltage

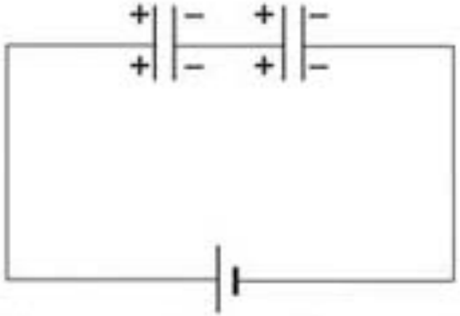
RC circuit



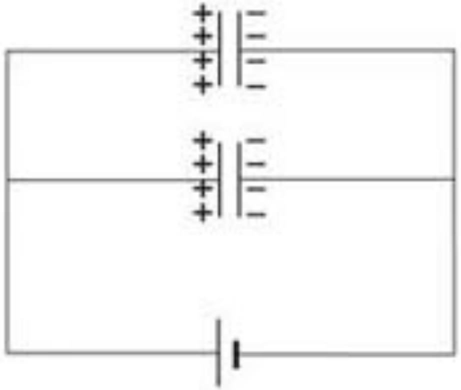
dielectric

$V = Ed$

increased capacitance



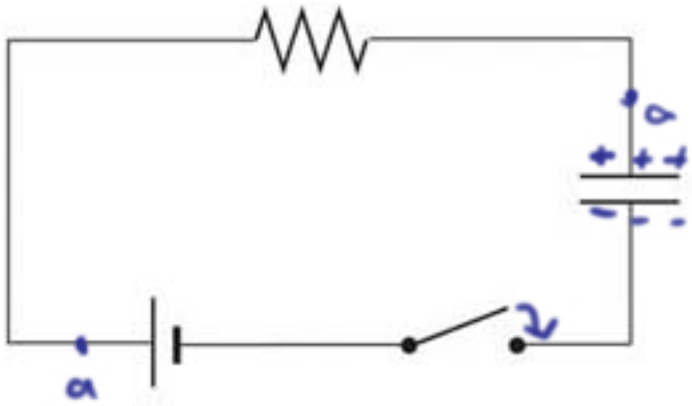
$$\frac{1}{C_{ser}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots$$



$$C_{par} = C_1 + C_2 + C_3 + \cdots$$

Placing capacitors in series decreases the total capacitance, while placing capacitors in parallel increases the total capacitance.

The RC circuit at right consists of a capacitor in series with a battery, resistor and a switch. What occurs within the circuit after the switch is closed?



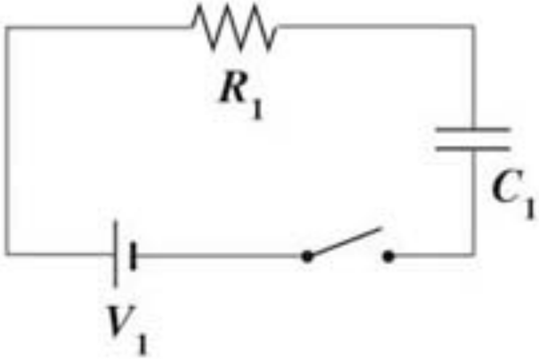
a. The voltage drop across the resistor decreases with time until there is no voltage acting across the resistor.

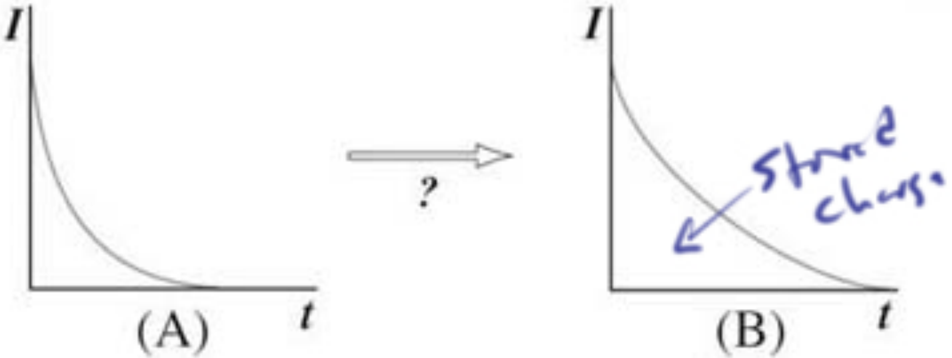
b. The current is not steady state. It slowly increases with time.

c. After the capacitor has fully charged, the current flows in the opposite direction.

d. The work done by the external voltage of the battery becomes stored potential energy in the charged capacitor.

Graph (A) shows the current vs. time that occurs after the switch is closed in the circuit at right. How could the circuit be altered to transform the current vs. time graph into graph (B)?





a. Include another resistor in series with R_1

b. Include another resistor in parallel with R_1

c. Include another capacitor in series with C_1

d. Include another capacitor in parallel with C_1