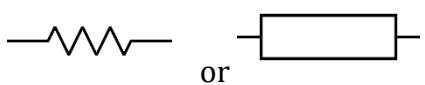
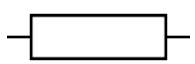


# CAPACITANCE VS. RESISTANCE

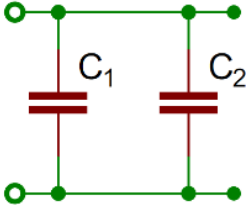
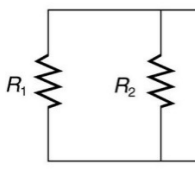
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Capacitor and resistor are two completely different devices. However, due to the similarity of their mathematical equations, students are sometimes confused when applying the mathematical formulas. The table below compares and contrasts these two electrical devices.

|                | Capacitor                                                                                                                                                                                                                                          | Resistor                                                                                                                                                                                                            |
|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Symbol         |                                                                                                                                                                   |  or                                            |
| Function       | Store energy                                                                                                                                                                                                                                       | Consume energy                                                                                                                                                                                                      |
| Measured by    | Capacitance (C)                                                                                                                                                                                                                                    | Resistance (R)                                                                                                                                                                                                      |
| Unit           | Farad (F)                                                                                                                                                                                                                                          | Ohm ( $\Omega$ )                                                                                                                                                                                                    |
| Formula        | $C = \frac{\epsilon_0 A}{d}$ <p><math>\epsilon_0</math>: permittivity of free space<br/> A: surface area of plates (<math>m^2</math>)<br/> d: distance between plates (m)</p> $C = \frac{Q}{V}$ <p>Q: charge of plates (C)<br/> V: voltage (V)</p> | $R = \frac{\rho L}{A}$ <p><math>\rho</math>: resistivity<br/> L: length of resistor (m)<br/> A: cross-sectional area of resistor (<math>m^2</math>)</p> $R = \frac{V}{I}$ <p>V: voltage (V)<br/> I: current (A)</p> |
| Energy/Power   | $U = \frac{Q^2}{2C} = \frac{1}{2} CV^2 = \frac{1}{2} QV$ <p>U: energy (J)</p>                                                                                                                                                                      | $P = VI = I^2 R = \frac{V^2}{R}$ <p>P: power (W)</p>                                                                                                                                                                |
| Series circuit |  $Q_{12} = Q_1 = Q_2$ $V_{12} = V_1 + V_2$ $\frac{1}{C_{12}} = \frac{1}{C_1} + \frac{1}{C_2}$                                                                   |  $I_{12} = I_1 = I_2$ $V_{12} = V_1 + V_2$ $R_{12} = R_1 + R_2$                                                                 |

# CAPACITANCE VS. RESISTANCE

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|                  |                                                                                                                                                  |                                                                                                                                                                                  |
|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Parallel circuit |  $Q_{12} = Q_1 + Q_2$ $V_{12} = V_1 = V_2$ $C_{12} = C_1 + C_2$ |  $I_{12} = I_1 + I_2$ $V_{12} = V_1 = V_2$ $\frac{1}{R_{12}} = \frac{1}{R_1} + \frac{1}{R_2}$ |
|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## Examples

1/ For the system of capacitors shown on the right, find

- Equivalent capacitance between b and c, and between a and c,
- the voltage across and the charge stored in each capacitor if a voltage of 21V is applied through ac,
- Energy stored in each capacitor.

## Solutions:

(a)  $C_{bc} = 9.0 + 11 = 20 \text{ pF}$

$$\frac{1}{C_{ac}} = \frac{1}{15} + \frac{1}{20} = \frac{7}{60}$$

$$C_{ac} = \frac{60}{7} = 8.6 \text{ pF}$$

(b)  $Q_{ac} = C_{ac} \times V_{ac} = 8.6 \times 10^{-12} \times 21 = 1.8 \times 10^{-10} \text{ C}$

$$Q_{ab} = Q_{bc} = Q_{ac} = 1.8 \times 10^{-10} \text{ C}$$

$$V_{ab} = \frac{Q_{ab}}{C_{ab}} = \frac{1.8 \times 10^{-10} \text{ C}}{1.5 \times 10^{-11} \text{ C}} = 12 \text{ V}$$

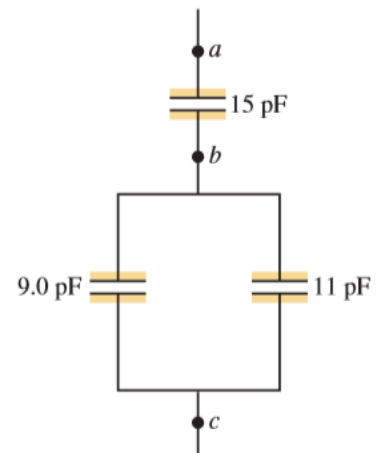
$$V_{bc} = V_{ac} - V_{ab} = 21 - 12 = 9.0 \text{ V}$$

$$V_{9.0 \text{ pF}} = V_{11 \text{ pF}} = V_{bc} = 9.0 \text{ V}$$

$$Q_{9.0 \text{ pF}} = 9.0 \times 10^{-12} \times 9.0 = 8.1 \times 10^{-11} \text{ C}$$

$$Q_{11 \text{ pF}} = 11 \times 10^{-12} \times 9.0 = 9.9 \times 10^{-11} \text{ C}$$

(c)  $U_{ab} = \frac{1}{2} Q_{ab} \times V_{ab} = \frac{1}{2} \times 1.8 \times 10^{-10} \times 12 = 1.1 \times 10^{-9} \text{ J}$



# CAPACITANCE VS. RESISTANCE

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$$U_{9.0pF} = \frac{1}{2} Q_{9.0pF} \times V_{9.0pF} = \frac{1}{2} \times 8.1 \times 10^{-11} \times 9.0 = 3.6 \times 10^{-10} J$$

$$U_{11pF} = \frac{1}{2} Q_{11pF} \times V_{11pF} = \frac{1}{2} \times 9.9 \times 10^{-11} \times 9.0 = 4.5 \times 10^{-10} J$$

2/ In the circuit shown on the right, the voltage across the 2.00-  $\Omega$  resistor is 12.0V. What are the emf of the battery and the current through the 6.00-  $\Omega$  resistor?

Solutions:

$$R_1 = 1.00\Omega; R_2 = 2.00\Omega; R_3 = 6.00\Omega$$

$$I_2 = \frac{V_2}{R_2} = \frac{12.0}{2.00} = 6.00A$$

$$I_{12} = I_1 = I_2 = 6.00A$$

$$R_{12} = R_1 + R_2 = 1 + 2 = 3.00\Omega$$

$$\varepsilon = V_3 = V_{12} = I_{12} \times R_{12} = 6.00 \times 3.00 = 18V$$

$$I_3 = \frac{V_3}{R_3} = \frac{18.0}{6.00} = 3.00A$$

**Practice problems (Answer key is below)**

1/ For the system of capacitors shown on the right, a potential difference of 25 V is maintained across ab.

(a) What is the equivalent capacitance of this system between a and b?

(b) How much charge is stored by this system?

(c) How much charge does the 6.5-nF capacitor store?

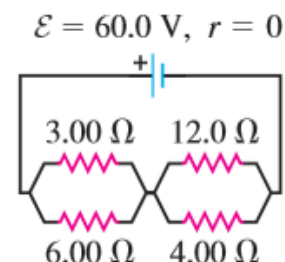
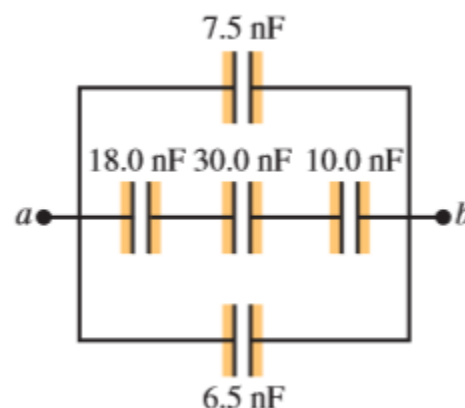
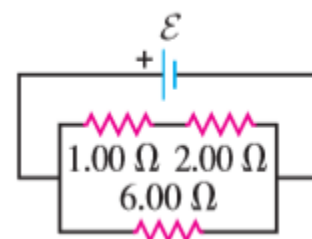
(d) What is the potential difference across the 7.5-nF capacitor?

2/ Compute the equivalent resistance of the network in the circuit shown on the right. Find the current in each resistor, and the power of the battery. The battery has negligible internal resistance.

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*Reference:*

Kramer, Laird.Young, Hugh D. (2012) *Study guide, Sears & Zemansky's University physics, 13th edition, Young and Freedman /San Francisco, CA : Pearson,*



$$720W; I_2 = 3.00A; I_3 = 9.00A; I_4 = 4.00A; I_5 = 4.00A; I_6 = 9.00A; I_7 = 8.00A; I_8 = 9.00A; I_9 = 5.00A; I_{10} = 5.00A$$

$$1/ a) 19.3nF; b) 483nC; c) 162nC; d) 25V$$

**Answer key**