

CHAPTER

1

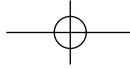
DC Review and Pre-Test

Electronics cannot be studied without first understanding the basics of electricity. This chapter is a review and pre-test on those aspects of direct current (DC) that apply to electronics. By no means does it cover the whole DC theory, but merely those topics that are essential to simple electronics. This chapter will review the following:

- Current flow
- Potential or voltage difference
- Ohm's law
- Resistors in series and parallel
- Power
- Small currents
- Resistance graphs
- Kirchhoff's voltage and current laws
- Voltage and current dividers
- Switches
- Capacitor charging and discharging
- Capacitors in series and parallel

Current Flow

- 1** Electrical and electronic devices work because of an electric current.



2 Chapter 1 ■ DC Review and Pre-Test

Question

What is an electric current?

Answer

An electric current is a flow of electric charge. The electric charge usually consists of negatively charged electrons. However, in semiconductors, there are also positive charge carriers called *holes*.

2 There are several methods that can be used to generate an electric current.

Question

Write at least three ways an electron flow (or current) can be generated.

Answers

The following is a list of the most common ways to generate current:

Magnetically — The induction of electrons in a wire rotating within a magnetic field. An example of this would be generators turned by water, wind, or steam, or the fan belt in a car.

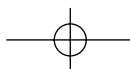
Chemically — Involving electrochemical generation of electrons by reactions between chemicals and electrodes (as in batteries).

Photovoltaic generation of electrons — When light strikes semiconductor crystals (as in solar cells).

Less common methods to generate an electric current include the following:

Thermal generation — Using temperature differences between thermocouple junctions. Thermal generation is used in generators on spacecraft that are fueled by radioactive material.

Electrochemical reaction — Occurring between hydrogen, oxygen, and electrodes (fuel cells).



Piezoelectrical — Involving mechanical deformation of piezoelectric substances. For example, piezoelectric material in the heels of shoes power LEDs that light up when you walk.

3 Most of the simple examples in this book will contain a battery as the voltage source. As such, the source provides a potential difference to a circuit that will enable a current to flow. An *electric current* is a flow of electric charge. In the case of a battery, electrons are the electric charge, and they flow from the terminal that has an excess number of electrons to the terminal that has a deficiency of electrons. This flow takes place in any complete circuit that is connected to battery terminals. It is this difference of charge that creates the potential difference in the battery. The electrons are trying to balance the difference.

Because electrons have a negative charge, they actually flow from the negative terminal and return to the positive terminal. We call this direction of flow *electron flow*. Most books, however, use current flow, which is in the opposite direction. It is referred to as *conventional current flow* or simply *current flow*. In this book, the term conventional current flow is used in all circuits.

Later in this book, you will see that many semiconductor devices have a symbol that contains an arrowhead pointing in the direction of conventional current flow.

Questions

- A. Draw arrows to show the current flow in Figure 1-1. The symbol for the battery shows its polarity.

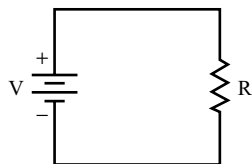


Figure 1-1

- B. What indicates that a potential difference is present?

- C. What does the potential difference cause?

- D. What will happen if the battery is reversed?

4 Chapter 1 ■ DC Review and Pre-Test

Answers

A. See Figure 1-2.

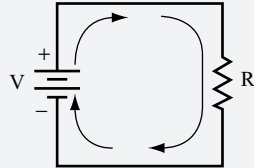


Figure 1-2

- B. The battery symbol indicates that a difference of potential, also called *voltage*, is being supplied to the circuit.
- C. Voltage causes current to flow if there is a complete circuit present, as shown in Figure 1-1.
- D. The current will flow in the opposite direction.

Ohm's Law

4 Ohm's law states the fundamental relationship between voltage, current, and resistance.

Question

What is the algebraic formula for Ohm's law?

Answer

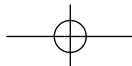
$$V = I \times R$$

This is the most basic equation in electricity, and you should know it well. Note that some electronics books state Ohm's law as $E = IR$. E and V are both symbols for voltage. This book uses V throughout. Also, in this formula, resistance is the opposition to current flow. Note that larger resistance results in smaller current for any given voltage.

5 Use Ohm's law to find the answers in this problem.

Questions

What is the voltage for each combination of resistance and current values?



Ohm's Law 5

- A. $R = 20$ ohms $I = 0.5$ amperes $V =$ _____
 B. $R = 560$ ohms $I = 0.02$ amperes $V =$ _____
 C. $R = 1000$ ohms $I = 0.01$ amperes $V =$ _____
 D. $R = 20$ ohms $I = 1.5$ amperes $V =$ _____

Answers

- A. 10 volts
 B. 11.2 volts
 C. 10 volts
 D. 30 volts

- 6** You can rearrange Ohm's law to calculate current values.

Questions

What is the current for each combination of voltage and resistance values?

- A. $V = 1$ volt $R = 2$ ohms $I =$ _____
 B. $V = 2$ volts $R = 10$ ohms $I =$ _____
 C. $V = 10$ volts $R = 3$ ohms $I =$ _____
 D. $V = 120$ volts $R = 100$ ohms $I =$ _____

Answers

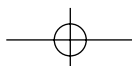
- A. 0.5 amperes
 B. 0.2 amperes
 C. 3.3 amperes
 D. 1.2 amperes

- 7** You can rearrange Ohm's law to calculate resistance values.

Questions

What is the resistance for each combination of voltage and current values?

- A. $V = 1$ volt $I = 1$ ampere $R =$ _____
 B. $V = 2$ volts $I = 0.5$ ampere $R =$ _____
 C. $V = 10$ volts $I = 3$ amperes $R =$ _____
 D. $V = 50$ volts $I = 20$ amperes $R =$ _____



6 Chapter 1 ■ DC Review and Pre-Test**Answers**

- A. 1 ohm
- B. 4 ohms
- C. 3.3 ohms
- D. 2.5 ohms

8 Work through these examples. In each case, two factors are given and you must find the third.

Questions

What are the missing values?

- A. 12 volts and 10 ohms. Find the current.

- B. 24 volts and 8 amperes. Find the resistance.

- C. 5 amperes and 75 ohms. Find the voltage.

Answers

- A. 1.2 amperes
- B. 3 ohms
- C. 375 volts

Resistors in Series

9 Resistors can be connected in series. Figure 1-3 shows two resistors in series.

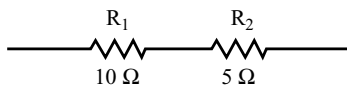


Figure 1-3

Question

What is their total resistance?

Answer

$$R_T = R_1 + R_2 = 10 \text{ ohms} + 5 \text{ ohms} = 15 \text{ ohms}$$

The total resistance is often called the *equivalent series resistance*, and is denoted as R_{eq} .

Resistors in Parallel

10 Resistors can be connected in parallel, as shown in Figure 1-4.

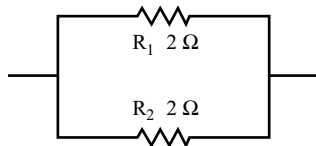


Figure 1-4

Question

What is the total resistance here?

Answer

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{2} + \frac{1}{2} = 1; \text{ thus } R_T = 1 \text{ ohm}$$

R_T is often called the *equivalent parallel resistance*.

11 The simple formula from problem 10 can be extended to include as many resistors as desired.

Question

What is the formula for three resistors in parallel?

8 Chapter 1 ■ DC Review and Pre-Test**Answer**

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

You will often see this formula in the following form:

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

12 In the following exercises, two resistors are connected in parallel.

Questions

What is the total or equivalent resistance?

- A. $R_1 = 1 \text{ ohm}$ $R_2 = 1 \text{ ohm}$ $R_T = \underline{\hspace{2cm}}$
 B. $R_1 = 1000 \text{ ohms}$ $R_2 = 500 \text{ ohms}$ $R_T = \underline{\hspace{2cm}}$
 C. $R_1 = 3600 \text{ ohms}$ $R_2 = 1800 \text{ ohms}$ $R_T = \underline{\hspace{2cm}}$

Answers

- A. 0.5 ohms
 B. 333 ohms
 C. 1200 ohms

Note that R_T is always smaller than the smallest of the resistors in parallel.

Power

13 When current flows through a resistor, it dissipates power, usually in the form of heat. Power is expressed in terms of watts.

Question

What is the formula for power?

Answer

There are three formulas for calculating power:

$$P = VI \text{ or } P = I^2R \text{ or } P = \frac{V^2}{R}$$

14 The first formula shown in problem 13 allows power to be calculated when only the voltage and current are known.

Questions

What is the power dissipated by a resistor for the following voltage and current values?

A. $V = 10$ volts $I = 3$ amperes $P =$ _____

B. $V = 100$ volts $I = 5$ amperes $P =$ _____

C. $V = 120$ volts $I = 10$ amperes $P =$ _____

Answers

A. 30 watts

B. 500 watts, or 0.5 kilowatts

C. 1200 watts, or 1.2 kilowatts

15 The second formula shown in problem 13 allows power to be calculated when only the current and resistance are known.

Questions

What is the power dissipated by a resistor given the following resistance and current values?

A. $R = 20$ ohm $I = 0.5$ ampere $P =$ _____

B. $R = 560$ ohms $I = 0.02$ ampere $P =$ _____

C. $V = 1$ volt $R = 2$ ohms $P =$ _____

D. $V = 2$ volt $R = 10$ ohms $P =$ _____

10 Chapter 1 ■ DC Review and Pre-Test**Answers**

- A. 5 watts
- B. 0.224 watts
- C. 0.5 watts
- D. 0.4 watts

16 Resistors used in electronics generally are manufactured in standard values with regard to resistance and power rating. Appendix D shows a table of standard resistance values. Quite often, when a certain resistance value is needed in a circuit, you must choose the closest standard value. This is the case in several examples in this book.

You must also choose a resistor with the power rating in mind. You should never place a resistor in a circuit that would require that resistor to dissipate more power than its rating specifies.

Questions

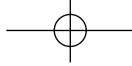
If standard power ratings for carbon composition resistors are 1/4, 1/2, 1, and 2 watts, what power ratings should be selected for the resistors that were used for the calculations in problem 15?

- A. For 5 watts _____
- B. For 0.224 watts _____
- C. For 0.5 watts _____
- D. For 0.4 watts _____

Answers

- A. 5 watt (or greater)
- B. 1/4 watt (or greater)
- C. 1/2 watt (or greater)
- D. 1/2 watt (or greater)

Most electronics circuits use low power carbon composition resistors. For higher power levels (such as the 5 watt requirement in question A), other types of resistors are available.



Small Currents

17 Although currents much larger than 1 ampere are used in heavy industrial equipment, in most electronic circuits, only fractions of an ampere are required.

Questions

A. What is the meaning of the term *milliampere*?

B. What does the term *microampere* mean?

Answers

A. A milliampere is one-thousandth of an ampere (that is, $1/1000$ or 0.001 amperes). It is abbreviated mA.

B. A microampere is one-millionth of an ampere (that is, $1/1,000,000$ or 0.000001 amperes). It is abbreviated μA .

18 In electronics, the values of resistance normally encountered are quite high. Often, thousands of ohms and occasionally even millions of ohms are used.

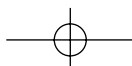
Questions

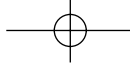
A. What does $\text{k}\Omega$ mean when it refers to a resistor?

B. What does $\text{M}\Omega$ mean when it refers to a resistor?

Answers

A. Kiloohm ($\text{k} = \text{kilo}$, $\Omega = \text{ohm}$). The resistance value is thousands of ohms. Thus, $1 \text{ k}\Omega = 1,000$ ohms, $2 \text{ k}\Omega = 2,000$ ohms, and $5.6 \text{ k}\Omega = 5,600$ ohms.





12 Chapter 1 ■ DC Review and Pre-Test

- B. Megohm (M = mega, Ω = ohm). The resistance value is millions of ohms. Thus, $1 \text{ M}\Omega = 1,000,000$ ohms, and $2.2 \text{ M}\Omega = 2,200,000$ ohms.

19 The following exercise is typical of many performed in transistor circuits. In this example, 6 V is applied across a resistor and 5 mA of current is required to flow through the resistor.

Question

What value of resistance must be used and what power will it dissipate?

R = _____ P = _____

Answer

$$R = \frac{V}{I} = \frac{6 \text{ V}}{5 \text{ mA}} = \frac{6}{0.005} = 1200 \text{ ohms} = 1.2 \text{ k}\Omega$$

$$P = V \times I = 6 \times 0.005 = 0.030 \text{ watts} = 30 \text{ mW}$$

20 Now, try these two simple examples.

Questions

What is the missing value?

- A. 50 volts and 10 mA. Find the resistance.

- B. 1 volt and 1 M Ω . Find the current.

Answers

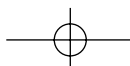
A. 5 k Ω

B. 1 μA

The Graph of Resistance

21 The voltage drop across a resistor and the current flowing through it can be plotted on a simple graph. This graph is called a *V-I curve*.

Consider a simple circuit in which a battery is connected across a 1 k Ω resistor.



The Graph of Resistance 13**Questions**

A. Find the current flowing if a 10 V battery is used.

B. Find the current when a 1 V battery is used.

C. Now find the current when a 20 V battery is used.

Answers

A. 10 mA

B. 1 mA

C. 20 mA

22 Plot the points of battery voltage and current flow from problem 21 on the graph shown in Figure 1-5, and connect them together.

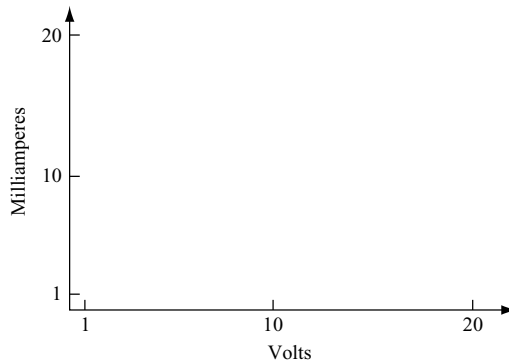


Figure 1-5

Answer

You should have drawn a straight line, as in the graph shown in Figure 1-6.

Sometimes you need to calculate the slope of the line on a graph. To do this, pick two points and call them A and B.

For point A let $V = 5$ volts and $I = 5$ mA

For point B let $V = 20$ volts and $I = 20$ mA

14 Chapter 1 ■ DC Review and Pre-Test

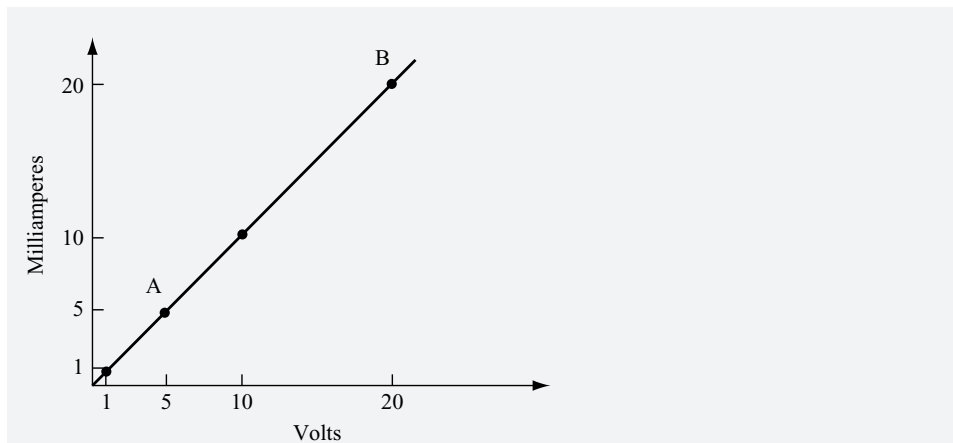


Figure 1-6

The slope can be calculated with the following formula:

$$\text{Slope} = \frac{V_B - V_A}{I_B - I_A} = \frac{20 \text{ volts} - 5 \text{ volts}}{20 \text{ mA} - 5 \text{ mA}} = \frac{15 \text{ volts}}{15 \text{ mA}} = \frac{15 \text{ volts}}{0.015 \text{ A}} = 1 \text{ k}\Omega$$

In other words, the slope of the line is equal to the resistance.

Later, you will learn about V-I curves for other components. They have several uses, and often they are not straight lines.

The Voltage Divider

23 The circuit shown in Figure 1-7 is called a *voltage divider*. It is the basis for many important theoretical and practical ideas you encounter throughout the entire field of electronics.

The object of this circuit is to create an output voltage (V_0) that you can control based upon the two resistors and the input voltage. Note that V_0 is also the *voltage drop* across R_2 .

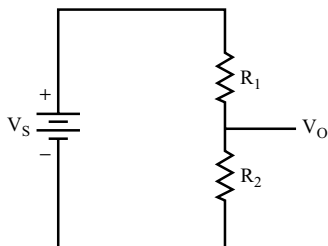


Figure 1-7

The Voltage Divider 15**Question**

What is the formula for V_0 ?

Answer

$$V_o = V_S \times \frac{R_2}{R_1 + R_2}$$

Note that $R_1 + R_2 = R_T$, the total resistance of the circuit.

24 A simple example will demonstrate the use of this formula.

Question

For the circuit shown in Figure 1-8, what is V_0 ?

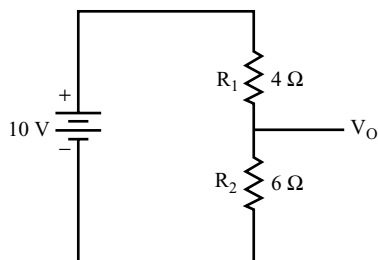


Figure 1-8

Answer

$$\begin{aligned} V_0 &= V_S \times \frac{R_2}{R_1 + R_2} \\ &= 10 \times \frac{6}{4 + 6} \\ &= 10 \times \frac{6}{10} \\ &= 6 \text{ volts} \end{aligned}$$

25 Now, try these problems.

16 Chapter 1 ■ DC Review and Pre-Test**Questions**

What is the output voltage for each combination of supply voltage and resistance?

- A. $V_S = 1$ volt $R_1 = 1$ ohm $R_2 = 1$ ohm $V_0 =$ _____
- B. $V_S = 6$ volts $R_1 = 4$ ohms $R_2 = 2$ ohms $V_0 =$ _____
- C. $V_S = 10$ volts $R_1 = 3.3$ k Ω $R_2 = 5.6$ k Ω $V_0 =$ _____
- D. $V_S = 28$ volts $R_1 = 22$ k Ω $R_2 = 6.2$ k Ω $V_0 =$ _____

Answers

- A. 0.5 volts
- B. 2 volts
- C. 6.3 volts
- D. 6.16 volts

26 The output voltage from the voltage divider is always less than the applied voltage. Voltage dividers are often used to apply specific voltages to different components in a circuit. Use the voltage divider equation to answer the following questions.

Questions

- A. What is the voltage drop across the 22k resistor for question D of problem 25?
- _____
- B. What total voltage do you get if you add this voltage drop to the voltage drop across the 6.2k resistor?
- _____

Answers

- A. 21.84 volts
- B. The sum is 28 volts.

Note that the voltages across the two resistors add up to the supply voltage. This is an example of Kirchhoff's voltage law (KVL), which simply means that the voltage supplied to a circuit must equal the sum of the

voltage drops in the circuit. In this book, KVL will often be used without actual reference to the law.

Also notice that voltage drop across a resistor is proportional to the resistor's value. Therefore, if one resistor has a greater value than another in a series circuit, the voltage drop across the higher value resistor will be greater.

The Current Divider

27 In the circuit shown in Figure 1-9, the current splits or divides between the two resistors that are connected in parallel.

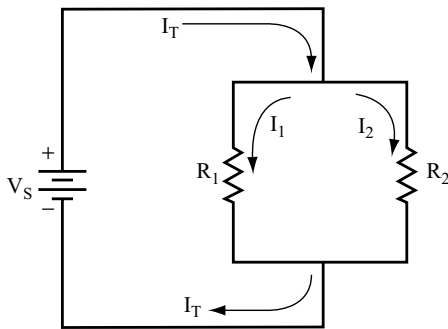


Figure 1-9

I_T splits into the individual currents I_1 and I_2 , and then these recombine to form I_T .

Question

Which of the following relationships are valid for this circuit?

- A. $V_S = R_1 I_1$
- B. $V_S = R_2 I_2$
- C. $R_1 I_1 = R_2 I_2$
- D. $I_1 / I_2 = R_2 / R_1$

Answer

All of them are valid.

18 Chapter 1 ■ DC Review and Pre-Test

23 When solving current divider problems, follow these steps:

1. Set up the ratio of the resistors and currents.

$$I_1/I_2 = R_2/R_1$$

2. Rearrange the ratio to give I_2 in terms of I_1 :

$$I_2 = I_1 \times \frac{R_1}{R_2}$$

3. From the fact that $I_T = I_1 + I_2$, express I_T in terms of I_1 only.
4. Now, find I_1 .
5. Now, find the remaining current (I_2).

Question

The values of two resistors in parallel and the total current flowing through the circuit are shown in Figure 1-10. What is the current through each individual resistor?

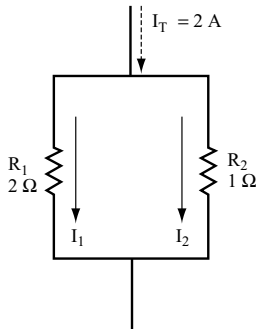
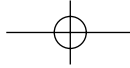


Figure 1-10

Answers

Working through the steps as shown:

1. $I_1/I_2 = R_2/R_1 = 1/2$
2. $I_2 = 2I_1$
3. $I_T = I_1 + I_2 = I_1 + 2I_1 = 3I_1$
4. $I_1 = I_T/3 = 2/3\ \text{A}$
5. $I_2 = 2I_1 = 4/3\ \text{A}$



The Current Divider 19

29 Now, try these problems. In each case, the total current and the two resistors are given. Find I_1 and I_2 .

Questions

A. $I_T = 30 \text{ mA}$, $R_1 = 12 \text{ k}\Omega$, $R_2 = 6 \text{ k}\Omega$

B. $I_T = 133 \text{ mA}$, $R_1 = 1 \text{ k}\Omega$, $R_2 = 3 \text{ k}\Omega$

C. What current do you get if you add I_1 and I_2 ?

Answers

A. $I_1 = 10 \text{ mA}$, $I_2 = 20 \text{ mA}$

B. $I_1 = 100 \text{ mA}$, $I_2 = 33 \text{ mA}$

C. They add back together to give you the total current supplied to the parallel circuit.

Note that question C is actually a demonstration of Kirchhoff's current law (KCL). This law simply stated says that the total current entering a junction in a circuit must equal the sum of the currents leaving that junction. This law will also be used on numerous occasions in later chapters. KVL and KCL together form the basis for many techniques and methods of analysis that are used in the application of circuit analysis.

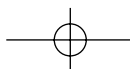
Also, notice that the current through a resistor is inversely proportional to the resistor's value. Therefore, if one resistor is larger than another in a parallel circuit, the current flowing through the higher value resistor will be the smaller of the two. Check your results for this problem to verify this.

30 You can also use the following equation to calculate the current flowing through a resistor in a two-branch parallel circuit:

$$I_1 = \frac{(I_T)(R_2)}{(R_1 + R_2)}$$

Question

Write the equation for the current I_2 .



20 Chapter 1 ■ DC Review and Pre-Test

Check the answers for the previous problem using these equations.

Answer

$$I_2 = \frac{(I_T)(R_1)}{(R_1 + R_2)}$$

Note that the current through one branch of a two-branch circuit is equal to the total current times the resistance of the opposite branch, divided by the sum of the resistances of both branches. This is an easy formula to remember.

Switches

31 A *mechanical switch* is a device that completes or breaks a circuit. The most familiar use is that of applying power to turn a device on or off. A switch can also permit a signal to pass from one place to another, prevent its passage, or route a signal to one of several places.

In this book we deal with two types of switches. The first is the simple on-off switch, also called a *single pole single throw* switch. The second is the *single pole double throw* switch. The circuit symbols for each are shown in Figure 1-11.



Figure 1-11

Two important facts about switches must be known.

- A closed (or ON) switch has the total circuit current flowing through it. There is *no* voltage drop across its terminals.
- An open (or OFF) switch has *no* current flowing through it. The full circuit voltage appears between its terminals.

The circuit shown in Figure 1-12 includes a closed switch.

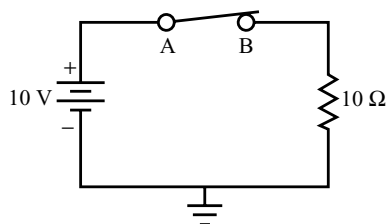


Figure 1-12

Questions

- A. What is the current flowing through the switch?
-
- B. What is the voltage at point A and point B with respect to ground?
-
- C. What is the voltage drop across the switch?
-

Answers

- A. $\frac{10 \text{ V}}{10 \text{ ohms}} = 1 \text{ ampere}$
- B. $V_A = V_B = 10 \text{ V}$
- C. 0 V (There is no voltage drop because both terminals are at the same voltage.)

- 32** The circuit shown in Figure 1-13 includes an open switch.

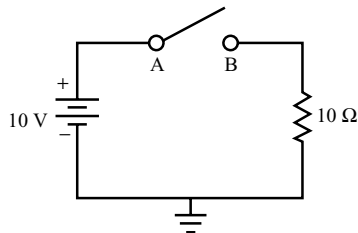


Figure 1-13

Questions

- A. What is the voltage at point A and point B?
-
- B. How much current is flowing through the switch?
-
- C. What is the voltage drop across the switch?
-

Answers

- A. $V_A = 10 \text{ V}; V_B = 0 \text{ V}$

22 Chapter 1 ■ DC Review and Pre-Test

- B. No current is flowing because the switch is open.
- C. 10 V. If the switch is open, point A is the same voltage as the positive battery terminal and point B is the same voltage as the negative battery terminal.

33 The circuit shown in Figure 1-14 includes a single pole double throw switch. The position of the switch determines whether lamp A or lamp B is lit.

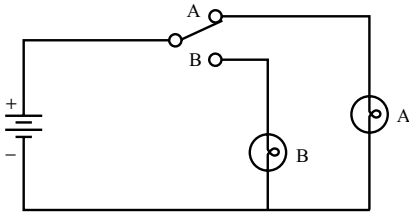


Figure 1-14

Questions

A. In the position shown, which lamp is lit?

B. Can both lamps be lit simultaneously?

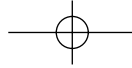
Answers

A. Lamp A.

B. No, one or the other must be off.

Capacitors in a DC Circuit

34 Capacitors are used extensively in electronics. They are used in both alternating current (AC) and DC circuits. Their main use in DC electronics is to become charged, hold the charge, and, at a specific time, release the charge.



Capacitors in a DC Circuit 23

The capacitor shown in Figure 1-15 charges when the switch is closed.

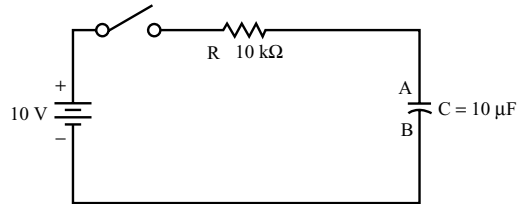


Figure 1-15

Question

To what final voltage will the capacitor charge?

Answer

It will charge up to 10 V. It will charge up to the voltage that would appear across an open circuit located at the same place where the capacitor is located.

35 How long does it take to reach this voltage? This is a most important question, with many practical applications. To find the answer you have to know the *time constant* (τ) of the circuit.

Questions

A. What is the formula for the time constant of this type of circuit?

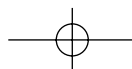
B. What is the time constant for the circuit shown in Figure 1-15?

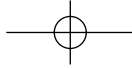
C. How long does it take the capacitor to reach 10 V?

D. To what voltage level does it charge in one time constant?

Answers

A. $\tau = R \times C$





24 Chapter 1 ■ DC Review and Pre-Test

- B. $\tau = 10 \text{ k}\Omega \times 10 \text{ }\mu\text{F} = 10,000 \text{ }\Omega \times 0.00001 \text{ F} = 0.1 \text{ seconds}$. (Convert resistance values to ohms and capacitance values to farads for this calculation.)
- C. Approximately 5 time constants, or about 0.5 seconds.
- D. 63 percent of the final voltage, or about 6.3 V.

36 The capacitor will not begin charging until the switch is closed. When a capacitor is uncharged or discharged, it has the same voltage on both plates.

Questions

A. What will be the voltage on plate A and plate B of the capacitor in Figure 1-15 before the switch is closed?

B. When the switch is closed, what will happen to the voltage on plate A?

C. What will happen to the voltage on plate B?

D. What will be the voltage on plate A after one time constant?

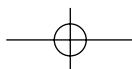
Answers

- A. Both will be at 0 V if the capacitor is totally discharged.
- B. It will rise towards 10 V.
- C. It will stay at 0 V.
- D. About 6.3 V.

37 The *capacitor charging graph* in Figure 1-16 shows for how many time constants a voltage must be applied to a capacitor before it reaches a given percentage of the applied voltage.

Questions

A. What is this type of curve called?



Capacitors in a DC Circuit 25

B. What is it used for?

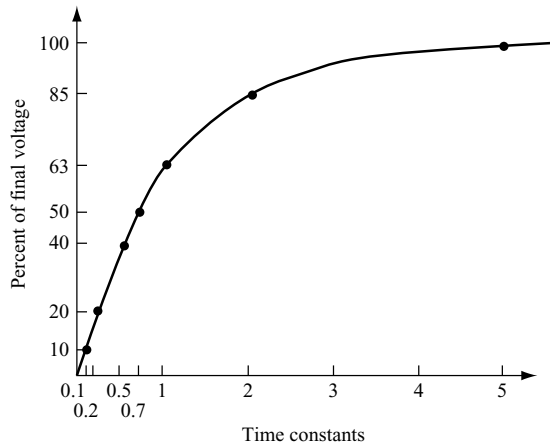


Figure 1-16

Answers

- A. It is called an *exponential* curve.
 B. It is used to calculate how far a capacitor has charged in a given time.
-

38 In the following, examples a resistor and a capacitor are in series. Calculate the time constant, how long it takes the capacitor to fully charge, and the voltage level after one time constant if a 10 V battery is used.

Questions

A. $R = 1 \text{ k}\Omega$ $C = 1000 \text{ }\mu\text{F}$

B. $R = 330 \text{ k}\Omega$ $C = 0.05 \text{ }\mu\text{F}$

Answers

- A. $\tau = 1 \text{ second}$; charge time = 5 seconds; $V_C = 6.3 \text{ V}$
 B. $\tau = 16.5 \text{ ms}$; charge time = 82.5 ms; $V_C = 6.3 \text{ V}$ (The abbreviation ms indicates milliseconds.)
-

26 Chapter 1 ■ DC Review and Pre-Test

39 The circuit shown in Figure 1-17 uses a double pole switch to create a discharge path for the capacitor.

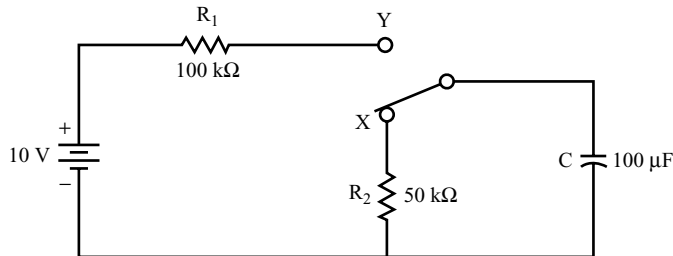


Figure 1-17

Questions

- A. With the switch in position X, what is the voltage on each plate of the capacitor?
- _____
- B. When the switch is moved to position Y, the capacitor begins to charge. What is its charging time constant?
- _____
- C. How long does it take to fully charge the capacitor?
- _____

Answers

- A. 0 V
- B. $\tau = R \times C = (100 \text{ k}\Omega) (100 \text{ }\mu\text{F}) = 10 \text{ secs}$
- C. Approximately 50 seconds

40 Suppose that the switch shown in Figure 1-17 is moved back to position X once the capacitor is fully charged.

Questions

- A. What is the discharge time constant of the capacitor?
- _____
- B. How long does it take to fully discharge the capacitor?
- _____

Answers

- A. $\tau = R \times C = (50 \text{ k}\Omega)(100 \text{ }\mu\text{F}) = 5 \text{ seconds}$ (discharging through the 50 k Ω resistor)
- B. Approximately 25 seconds

The circuit powering a camera flash is an example of a capacitor's ability to store charge and then discharge upon demand. While you wait for the flash unit to charge, the camera is using its battery to charge a capacitor. Once the capacitor is charged, it holds that charge until you click the shutter button, causing the capacitor to discharge, which powers the flash.

41 Capacitors can be connected in parallel, as shown in Figure 1-18.

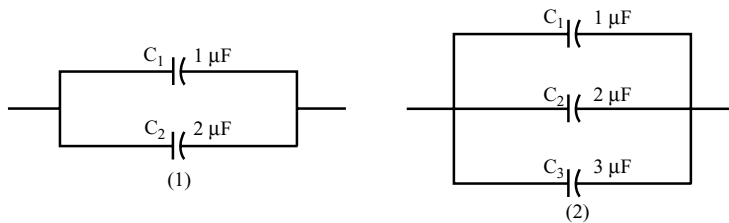


Figure 1-18

Questions

- A. What is the formula for the total capacitance?

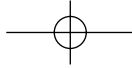
- B. What is the total capacitance in circuit 1?

- C. What is the total capacitance in circuit 2?

Answers

- A. $C_T = C_1 + C_2 + C_3 + \dots + C_N$
- B. $C_T = 1 + 2 = 3 \text{ }\mu\text{F}$
- C. $C_T = 1 + 2 + 3 = 6 \text{ }\mu\text{F}$

In other words, the total capacitance is found by simple addition of the capacitor values.


28 Chapter 1 ■ DC Review and Pre-Test

42 Capacitors can be placed in series, as shown in Figure 1-19.

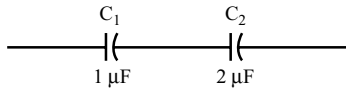


Figure 1-19

Questions

A. What is the formula for the total capacitance?

B. In Figure 1-19, what is the total capacitance?

Answers

A. $\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots + \frac{1}{C_N}$

B. $\frac{1}{C_T} = \frac{1}{1} + \frac{1}{2} = 1\frac{1}{2} = \frac{3}{2}$; thus $C_T = \frac{2}{3}$

43 In each of these examples the capacitors are placed in series. Find the total capacitance.

Questions

A. $C_1 = 10 \mu\text{F}$ $C_2 = 5 \mu\text{F}$

B. $C_1 = 220 \mu\text{F}$ $C_2 = 330 \mu\text{F}$ $C_3 = 470 \mu\text{F}$

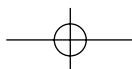
C. $C_1 = 0.33 \mu\text{F}$ $C_2 = 0.47 \mu\text{F}$ $C_3 = 0.68 \mu\text{F}$

Answers

A. $3.3 \mu\text{F}$

B. $103.06 \mu\text{F}$

C. $0.15 \mu\text{F}$



Summary

The few simple principles reviewed in this chapter are those you need to begin the study of electronics. Following is a summary of these principles:

- The basic electrical circuit consists of a source (voltage), a load (resistance), and a path (conductor or wire).
- The voltage represents a charge difference.
- If the circuit is a complete circuit, then electrons will flow in what is called current flow. The resistance offers opposition to current flow.
- The relationship between V , I , and R is given by Ohm's law:

$$V = I \times R$$

- Resistance could be a combination of resistors in series, in which case you add the values of the individual resistors together to get the total resistance.

$$R_T = R_1 + R_2 + \cdots + R_N$$

- Resistance could be a combination of resistors in parallel, in which case you find the total by using the following formula:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_N} \quad \text{or} \quad R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_N}}$$

- The power delivered by a source is found by using the following formula:

$$P = VI$$

- The power dissipated by a resistance is found by using the following formula:

$$P = I^2R \quad \text{or} \quad P = \frac{V^2}{R}$$

- If you know the total applied voltage, V_S , the voltage across one resistor in a series string of resistors is found by using the following voltage divider formula:

$$V_1 = \frac{V_S R_1}{R_T}$$

- The current through one resistor in a two resistor parallel circuit with the total current known is found by using the current divider formula:

$$I_1 = \frac{I_T R_2}{(R_1 + R_2)}$$

30 Chapter 1 ■ DC Review and Pre-Test

- Kirchhoff's voltage law (KVL) relates the voltage drops in a series circuit to the total applied voltage.

$$V_S = V_1 + V_2 + \cdots + V_N$$

- Kirchhoff's current law (KCL) relates the currents at a junction in a circuit by saying that the sum of the input currents equals the sum of the output currents. For a simple parallel circuit, this becomes the following where I_T is the input current:

$$I_T = I_1 + I_2 + \cdots + I_N$$

- A switch in a circuit is the control device that directs the flow of current or, in many cases, allows that current to flow.
- Capacitors are used to store electric charge in a circuit. They also allow current or voltage to change at a controlled pace. The circuit time constant is found by using the following formula:

$$\tau = R \times C$$

- At one time constant in an RC circuit, the values for current and voltage have reached 63 percent of their final values. At five time constants, they have reached their final values.
- Capacitors in parallel are added to find the total capacitance.

$$C_T = C_1 + C_2 + \cdots + C_N$$

- Capacitors in series are treated the same as resistors in parallel to find a total capacitance.

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_N} \quad \text{or} \quad C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots + \frac{1}{C_N}}$$

DC Pre-Test

The following problems and questions will test your understanding of the basic principles presented in this chapter. You will need a separate sheet of paper for your calculations. Compare your answers with the answers provided following the test. You will find that many of the problems can be worked more than one way.

Questions 1-5 use the circuit shown in Figure 1-20. Find the unknown values indicated using the values given.

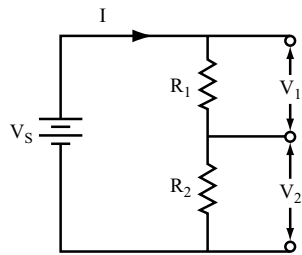


Figure 1-20

- $R_1 = 12 \text{ ohms}$, $R_2 = 36 \text{ ohms}$, $V_S = 24 \text{ V}$
 $R_T = \underline{\hspace{2cm}}$, $I = \underline{\hspace{2cm}}$
- $R_1 = 1 \text{ K}\Omega$, $R_2 = 3 \text{ K}\Omega$, $I = 5 \text{ mA}$
 $V_1 = \underline{\hspace{2cm}}$, $V_2 = \underline{\hspace{2cm}}$, $V_S = \underline{\hspace{2cm}}$
- $R_1 = 12 \text{ k}\Omega$, $R_2 = 8 \text{ k}\Omega$, $V_S = 24 \text{ V}$
 $V_1 = \underline{\hspace{2cm}}$, $V_2 = \underline{\hspace{2cm}}$
- $V_S = 36 \text{ V}$, $I = 250 \text{ mA}$, $V_1 = 6 \text{ V}$
 $R_2 = \underline{\hspace{2cm}}$
- Now, go back to problem 1. Find the power dissipated by each resistor and the total power delivered by the source.
 $P_1 = \underline{\hspace{2cm}}$, $P_2 = \underline{\hspace{2cm}}$, $P_T = \underline{\hspace{2cm}}$

Questions 6-8 will use the circuit shown in Figure 1-21. Again, find the unknowns using the given values.

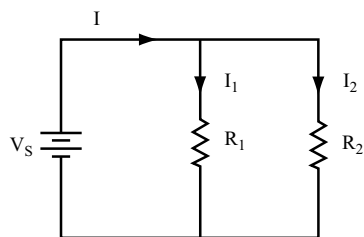
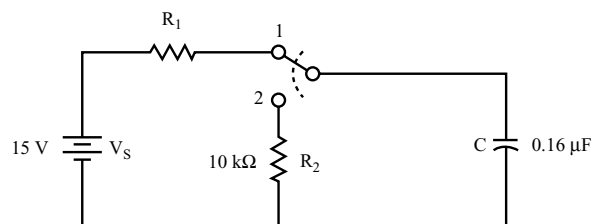


Figure 1-21

- $R_1 = 6 \text{ k}\Omega$, $R_2 = 12 \text{ k}\Omega$, $V_S = 20 \text{ V}$
 $R_T = \underline{\hspace{2cm}}$, $I = \underline{\hspace{2cm}}$
- $I = 2 \text{ A}$, $R_1 = 10 \text{ ohms}$, $R_2 = 30 \text{ ohms}$
 $I_1 = \underline{\hspace{2cm}}$, $I_2 = \underline{\hspace{2cm}}$

32 Chapter 1 ■ DC Review and Pre-Test

8. $V_S = 12\text{ V}$, $I = 300\text{ mA}$, $R_1 = 50\text{ ohms}$
 $R_2 = \underline{\hspace{2cm}}$, $P_1 = \underline{\hspace{2cm}}$
9. What is the maximum current that a 220 ohm resistor can safely have if its power rating is 1/4 watts?
 $I_{\text{MAX}} = \underline{\hspace{2cm}}$
10. In a series RC circuit the resistance is 1 k Ω , the applied voltage is 3 V, and the time constant should be 60 μsec .
- A. What is the required value of C?
 $C = \underline{\hspace{2cm}}$
- B. What will be the voltage across the capacitor 60 μsec after the switch is closed?
 $V_C = \underline{\hspace{2cm}}$
- C. At what time will the capacitor be fully charged?
 $T = \underline{\hspace{2cm}}$
11. In the circuit shown in Figure 1-22, when the switch is at position 1, the time constant should be 4.8 ms.
- A. What should be the value of resistor R_1 ?
 $R_1 = \underline{\hspace{2cm}}$
- B. What will be the voltage on the capacitor when it is fully charged, and how long will it take to reach this voltage?
 $V_C = \underline{\hspace{2cm}}$, $T = \underline{\hspace{2cm}}$
- C. After the capacitor is fully charged, the switch is thrown to position 2. What is the discharge time constant and how long will it take to completely discharge the capacitor?
 $\tau = \underline{\hspace{2cm}}$, $T = \underline{\hspace{2cm}}$


Figure 1-22

12. Three capacitors are available with the following values:

$$C_1 = 8 \mu\text{F}; C_2 = 4 \mu\text{F}; C_3 = 12 \mu\text{F}.$$

A. What is C_T if all three are connected in parallel?

$$C_T = \underline{\hspace{2cm}}$$

B. What is C_T if they are connected in series?

$$C_T = \underline{\hspace{2cm}}$$

C. What is C_T if C_1 is in series with the parallel combination of C_2 and C_3 ?

$$C_T = \underline{\hspace{2cm}}$$

Answers to DC Pre-Test

If your answers do not agree with those provided here, review the problems indicated in parentheses before you go on to the next chapter. If you still feel uncertain about these concepts, go to a Web site such as www.BuildingGadgets.com and work through DC tutorials listed there.

It is assumed that Ohm's law is well known, so problem 4 will not be referenced.

1.	$R_T = 48 \text{ ohms}, I = 0.5 \text{ A}$	(problem 9)
2.	$V_1 = 5 \text{ V}, V_2 = 15 \text{ V}, V_3 = 20 \text{ V}$	(problems 23 and 26)
3.	$V_1 = 14.4 \text{ V}, V_2 = 9.6 \text{ V}$	(problem 23 and 263)
4.	$R_2 = 120 \text{ ohms}$	(problems 9 and 23)
5.	$P_1 = 3 \text{ W}, P_2 = 9 \text{ W}, P_T = 12 \text{ W}$	(problems 9 and 13)
6.	$R_T = 4 \text{ k}\Omega, I = 5 \text{ mA}$	(problem 10)
7.	$I_1 = 1.5 \text{ A}, I_2 = 0.5 \text{ A}$	(problem 289)
8.	$R_2 = 200 \text{ ohms}, P_1 = 2.88 \text{ W}$	(problem 10 and 13)
9.	$I_{\text{MAX}} = 33.7 \text{ mA}$	(problems 13, 15 and 16)
10.	A. $C = 0.06 \mu\text{F}$	(problems 34 and 35)
	B. $V_C = 1.9 \text{ V}$	
	C. $T = 300 \mu\text{sec}$	(34–38)

34 Chapter 1 ■ DC Review and Pre-Test

11.	A.	$R_1 = 30 \text{ k}\Omega$	(problems 35, 39 and 40)
	B.	$V_C = 15 \text{ V}, T = 24 \text{ ms}$	
	C.	$\tau = 1.6 \text{ ms}, T = 8.0 \text{ ms}$	(39–40)
12.	A.	$24 \text{ }\mu\text{F}$	(problems 41 and 42)
	B.	$2.18 \text{ }\mu\text{F}$	
	C.	$5.33 \text{ }\mu\text{F}$	(42–43)