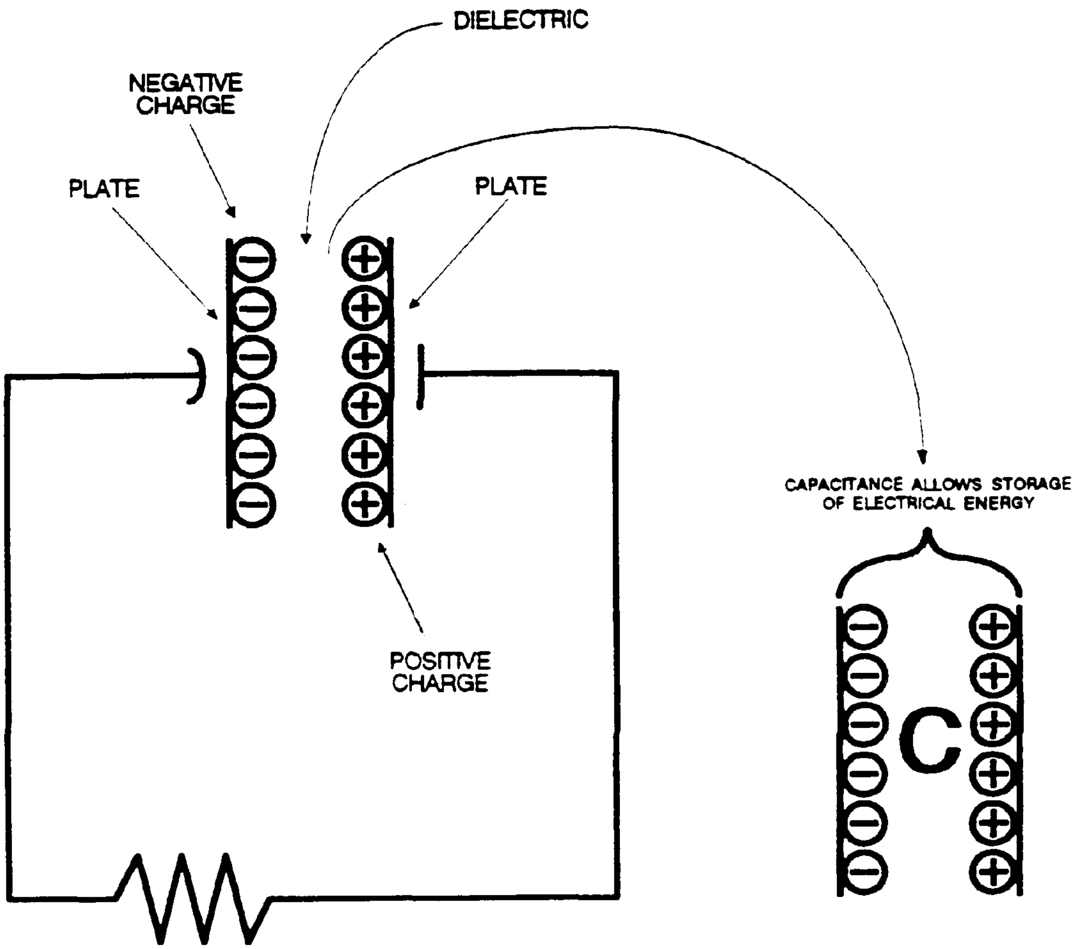
SUBCOURSE
IT0351

EDITION
A

US ARMY INTELLIGENCE CENTER

CAPACITANCE



THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT

ARMY CORRESPONDENCE COURSE PROGRAM

A I P D

READINESS / PROFESSIONALISM THRU GROWTH

Subcourse Number IT0351

EDITION A

US ARMY INTELLIGENCE CENTER
FORT HUACHUCA, AZ 85613-6000

4 Credit Hours

Edition Date: January 1997

SUBCOURSE OVERVIEW

This subcourse is designed to introduce the student to the basic unit of measurement, terms, and factors applicable to capacitors; solving problems related to working voltage, applied voltage, quantity of charge, RC time constant, and voltage across capacitors and resistors in an RC circuit.

This subcourse replaces SA 0745.

There are no prerequisites for this subcourse, however, it will be helpful if the student is knowledgeable of solving problems through powers-of-ten. Subcourse IT0332, Powers of Ten and Conversion of Electrical Units is recommended.

TERMINAL LEARNING OBJECTIVE:

ACTION: You will select the definitions for the basic units of measurement, terms, and factors applicable to capacitors. Also you will be required to solve for problems in working voltages, E_{app}, Q, t, E_C, and E_R.

CONDITION: You will have this subcourse booklet for self-paced study. All information required is contained in the subcourse.

STANDARD: To demonstrate competency of this task, you must achieve a minimum of 70% on the subcourse examination.

TABLE OF CONTENTS

LESSON 1

CAPACITANCE

OVERVIEW

LESSON DESCRIPTION

This lesson teaches the basic units of measurement, terms, and factors applicable to capacitors. It also teaches the equations and how to apply them for solving for working voltages, E_{app}, Q, t, E_C, and E_R.

TERMINAL LEARNING OBJECTIVE

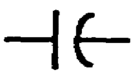
ACTION: You will select the definitions for the basic units of measurement, terms, and factors applicable to capacitors. Also you will be required to solve for problems in working voltages, E_{app}, Q, t, E_C, and E_R.

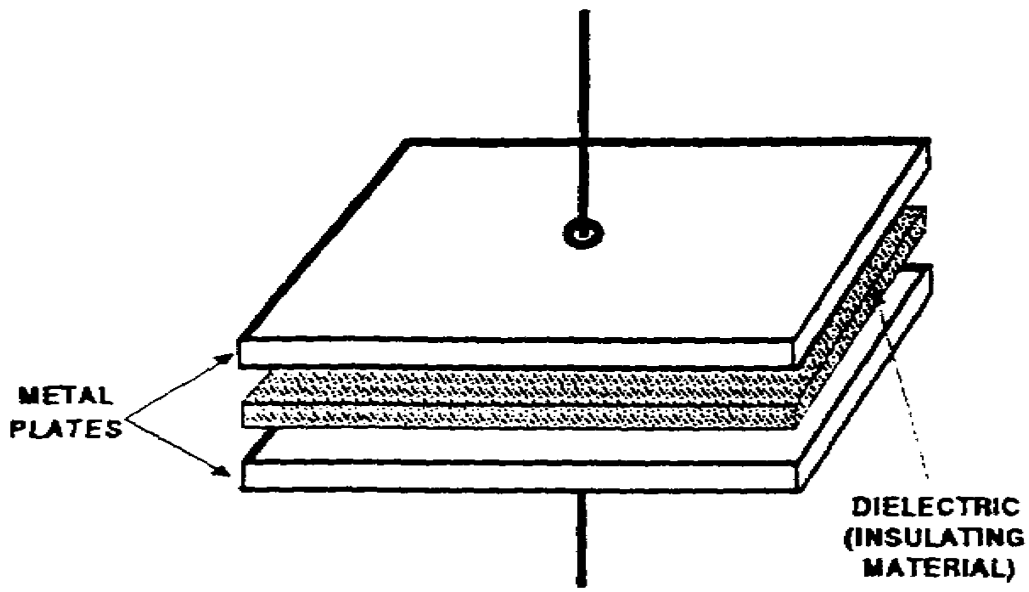
CONDITIONS: You will have this subcourse booklet for self-paced study. All information required is contained in the subcourse.

STANDARD: To demonstrate competency of this task, you must achieve a minimum of 70% on the subcourse examination.

INTRODUCTION: This subcourse is designed in a frame format. Each page consists of at least one frame with a left and right side. The right side of a frame contains the lesson information and a question or statement with a blank space. The left side contains the answer to the previous frames question or statement. In an electronic circuits, a capacitor is used to block DC voltages, pass AC voltages, or a combination of both.

	1. The basic unit of measurement of capacitance is the FARAD and is abbreviated __f__. A capacitor with two plates 1 millimeter apart, with an air dielectric, and with a plate area of 36 square miles, has a capacity of one farad. As you can readily see, the farad is too large a unit for practical purposes. Consequently capacitance is commonly measured in microfarads or picofarads. A microfarads one one-millionth of a farad (10^{-6}). A picofarad is one one-millionth of a microfarad (10^{-12}). The abbreviations for microfarad and picofarad are uf and pf respectively. The FARAD is the basic unit of measurement of capacitance and is abbreviated ____________________.
f	2. The abbreviation for the basic unit of measurement of capacitance is f. The basic unit of measurement of capacitance is the___________________.
FARAD	3. The abbreviation for capacitance, capacity, and/or capacitor is__C__. The schematic symbol for a capacitor is  . **NOTE: The term capacitance and capacity are often used interchangeably.** The schematic symbol for a capacitor is  the abbreviation is _____________.
C	4. The schematic symbol,______________, is the symbol for a capacitor; the abbreviation for capacitance is________________________.

 C	5. The basic unit of measurement of capacitance is the __________________which is abbreviated_______________.
FARAD f	6. The COULOMB is the unit of measurement of the QUANTITY of electrons which can be stored in a capacitor. The symbol for the QUANTITY of electrons is__Q__. (You should recall that one COULOMB equals 6.28 x 10^{18} electrons.) The unit of measurement of the quantity of electrons which can be stored in a capacitor is the COULOMB. The symbol for the quantity of electrons is_________.
Q	7. The symbol for the quantity of electrons on a capacitor is Q. The unit of measurement of the quantity of electrons on a capacitor is the_______________.
COULOMB	8. The abbreviation for capacitance, capacity, and/or capacitor is _______________;the schematic symbol for a capacitor is______________________.
C 	9. What are the name and the abbreviation for the basic unit of measurement of capacitance? NAME: ABBREVIATION:
FARAD f	10. The unit of measurement of the quantity of electrons stored in a capacitor is the _______________. The symbol for quantity of electronics is____________________.
COULOMB Q	11. Draw the schematic symbol of a capacitor, and write the abbreviation for capacitance. SCHEMATIC SYMBOL: ABBREVIATION:

 C	12. What are the name and symbol for the basic unit of measurement of quantity of electrons on a capacitor? NAME: SYMBOL
COULOMB Q	13. A capacitor has a capacitance (C) of one FARAD (f) when one COULOMB (Q) of electrons is stored in the capacitor with one VOLT applied.
No answer required.	14. When we use the term "the dielectric of a capacitor" we are referring to the INSULATING MATERIAL WHICH SEPARATES THE PLATES of the capacitor.  We define the dielectric of a capacitor as the ______________________material which separates the___________________________.
Insulating plates	15. As applied to capacitors, the term "dielectric" refers to the ____ ____ ____

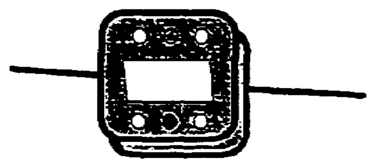
Insulating material which separates the plates.

16. Any material which has insulating qualities can be used as a dielectric; however, materials most satisfactory and commonly used as the dielectric in capacitors are:

a. Air	d. Paper
b. Mica	e. Glycerin
c. Glass	f. Ceramic

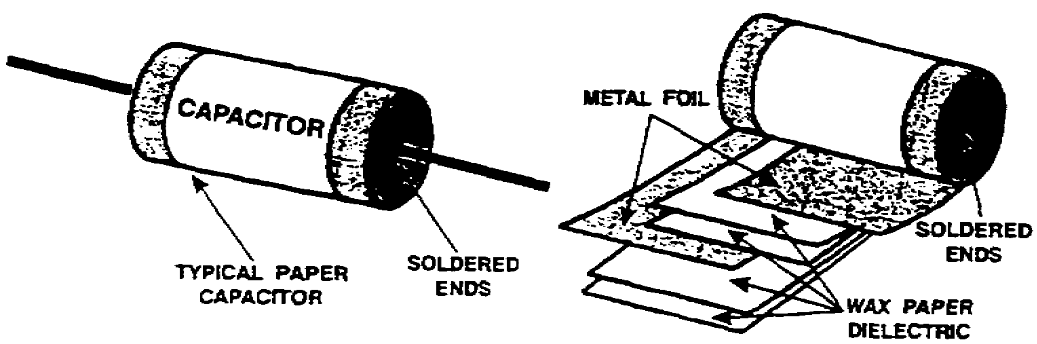
Capacitors are often referred to in terms of the type of dielectric used:

A mica capacitor contains a mica dielectric.



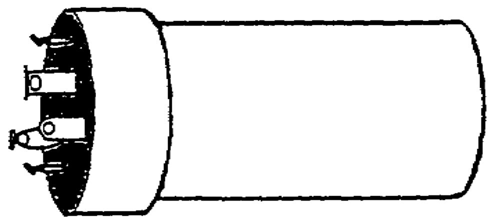
TYPICAL MICA CAPACITOR

A paper capacitor contains a paper dielectric.



Materials commonly used as the dielectric in capacitors are:

a. Mica
b. Paper
c. ______________
d. ______________
e. ______________
f. ______________

c. Air d. Glass e. Glycerin f. Ceramic	17. A ceramic capacitor contains a ceramic dielectric.  TYPICAL CERAMIC CAPACITORS An electrolytic capacitor usually contains an aluminum oxide film as the dielectric.  TYPICAL ELECTROLYTIC CAPACITOR Electrolytic capacitors must not be used with AC voltages. <u>They are designed for use with DC voltages only and must always be connected in accordance with the polarity markings.</u> Common capacitor dielectric materials are: a. Glycerin d.________________ b. Ceramic e.________________ c. ________________ f.________________
c. Air d. Glass e. Mica f. Paper	18. Write the definition for the term "dielectric" as applied to capacitors.
The insulating materials which separates the plates.	19. The measure of the ability of an insulating material to support an electrostatic field, as compared to air, is called the dielectric constant. The symbol for dielectric constant is k. The small letter k is the symbol for ____

dielectric constant	20. When a voltage is applied across a capacitor, the orbits of the electrons in the dielectric are distorted by the electrostatic field which exists between the charged plates of the capacitor. See figure 1.

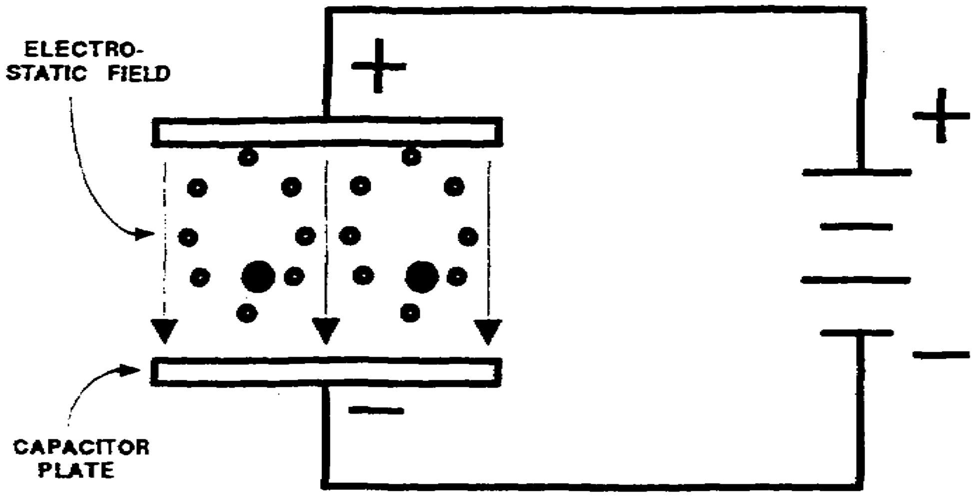


Figure 1.

The better the insulating ability of the material used as the dielectric, the greater the voltage we can apply across the capacitor without the dielectric breaking down or arcing through. A better insulator permits use of a stronger electrostatic field, resulting in a higher capacity.

- The fewer free electrons there are in a material, the better is its insulating ability.

The definition for the term dielectric constant is: A MEASURE OF THE ABILITY OF A MATERIAL TO SUPPORT AN ELECTROSTATIC FIELD AS

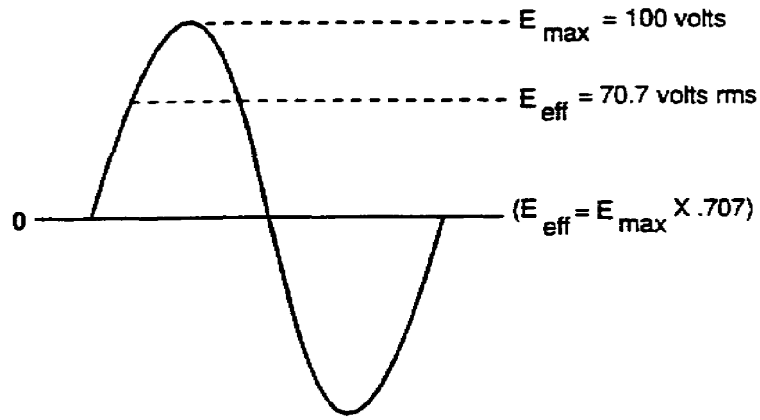
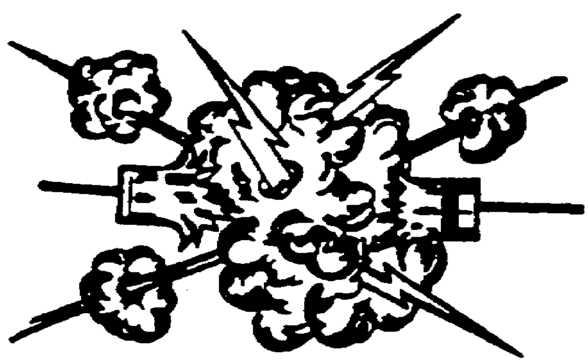
____.

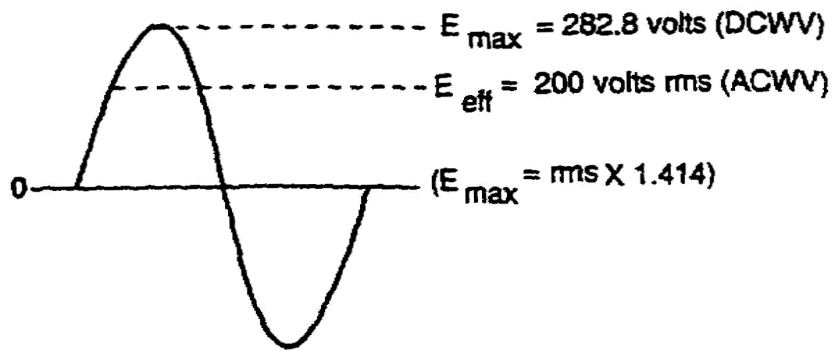
The symbol for dielectric constant is __________________.

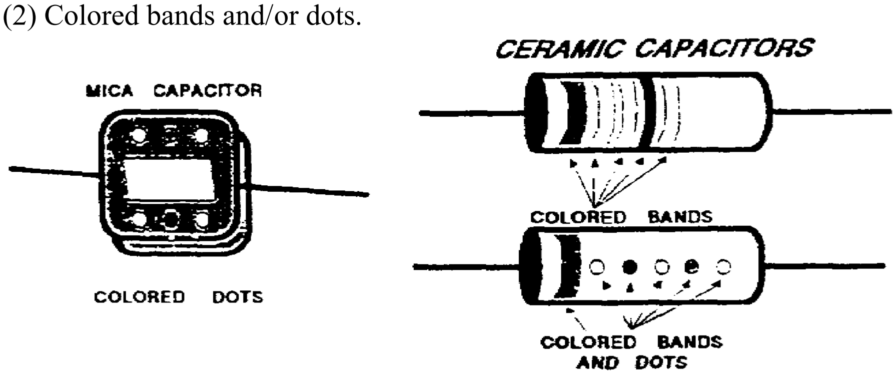
compared to air k	21. Write the definition for the term "dielectric" as applied to capacitors.
The insulating material which separates the plates.	22. The capacity of a capacitor depends on tree factors: (1) The dielectric constant of the dielectric (k). (2) The area of the plates (A) in square inches. (3) The distance (the thickness of the dielectric material) between the plates (d). The capacity of a capacitor is determined at the time of manufacture by the actual physical construction of the capacitor, and with the exception of variable capacitors (which normally use air or mica as the dielectric), the capacity cannot be changed. Three factors which determine the capacity of a capacitor are: (1) The dielectric constant (k). (2) (3)
(2) Plate area (A). (3) Distance between plates (d).	23. The relationship of the three factors which determine the capacity of a capacitor can be seen by using the formula: $C = \frac{k\,A}{d}$ Where $C = \frac{\text{dielectric constant(k) x plate area (A)}}{\text{distance between plates (d)}}$ List the three factors which determine the capacitance of a capacitor. (1) (2) (3)

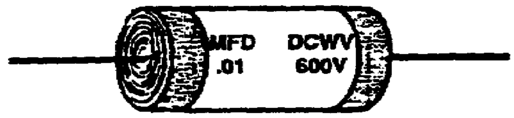
(1) Dielectric constant (2) Plate area (3) Distance between plates	24. Dry air is used as the standard for dielectric constant and has a dielectric constant (k) of 1. Dielectric constants of some of the commonly used dielectric materials are: **Dielectric** / **k**: Air 1.0; Paper (wax) 3.1; Glass 4.2 **Dielectric** / **k**: Mica 6.0; Bakelite 6.0; Glycerin 56.2 Referring to the formula $C = \frac{kA}{d}$ you can see that if two capacitors have the same plate area (A) and the same distance between plates (d), but one has an air dielectric (k = 1) and the other capacitor has a mica dielectric (k - 6.0), the capacitor with the mica dielectric has the higher capacity. The symbol for dielectric constant is ___________________________ . The definition for the term dielectric constant is:
k The ability of a material to support an electrostatic field as <u>compared to air.</u>	25. List four materials commonly used as the dielectric materials in capacitors. (1) (3) (2) (4)
<u>Any four</u> Air Mica Glass Paper Glycerin Ceramic	26. The three factors which determine the capacitance of a capacitor are: HINT: $C = \frac{k\ A}{d}$ (1) (2) (3)

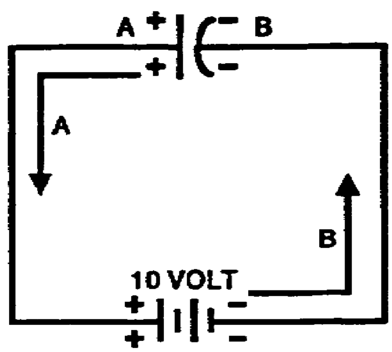
(1) Dielectric constant (k) (2) Plate area (A) (3) Distance between plates (d)	27. What is the symbol and the definition for the term "dielectric constant"? SYMBOL DEFINITION:
k The ability of a material to support an electrostatic field as compared to air.	28. List the tree factors which determine the capacitance of a capacitor. (1) (2) (3)
(1) Dielectric constant (k) (2) Plate area (A) (3) Distance between plates (d)	29. All capacitors are rated as to their DC working voltage (DCWV). This is the maximum DC voltage they can be safety applied across the capacitor without danger of breaking down the dielectric and arcing between the plates. The maximum value of DC voltage that can be safely applied across a capacitor is called the____.
DC working voltage or DCWV	30. The DC working voltage (DCWV) is normally printed or stamped on the body of the capacitor. For example: A capacitor has 100 DCWD printed on the body. This indicates that_____________volts is the___________________________DC voltage that can be safely applied to that capacitor without danger of arcing between the plates.

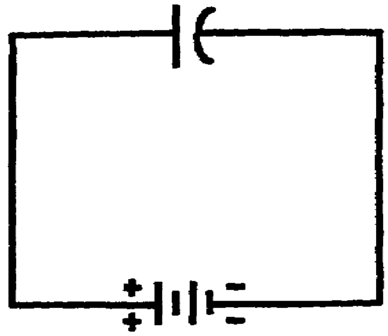
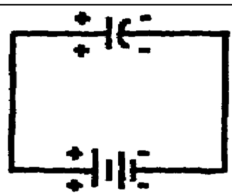
100 maximum	31. The AC working voltage (ACWV) of a capacitor is always .707 x the DCWV. This is because the maximum AC voltage applied to a capacitor must not exceed the DCWV of that capacitor. In an AC circuit, when E_{max} = 100 volts, E_{eff} = .707 x 100 volts = 70.7 volts. See the AC waveform below.  A capacitor rated at 150 DCWV has an ACWV of____________________volts rms.
106.05	32. A capacitor rated at 200 DCWV is placed in an AC circuit with an E_{eff} of 176.75 volts rms. The capacitor goes:  Why did the capacitor blow?

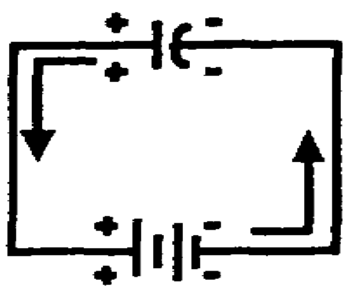
Because the ACWV of the capacitor is only 141.4 volts.	33. What is meant by the DC working voltage (DCWV) of a capacitor?
The highest DC voltage that can be safely applied to a capacitor.	34. An AC circuit indicates 200 volts rms on an AC voltmeter. A capacitor used in this circuit must have a DCWV of at least 200 x 1.414, or 282.8 volts. (The maximum AC voltage must not exceed the DCWV.) See the AC waveform.  An AC voltmeter indicates 100 volts rms in a circuit. To be safely used in this circuit, a capacitor must have a DCWV of at least _____________ volts.
141.4	35. A capacitor with an ACWV of 240 volts has a DCWV of_______________volts. This capacitor cannot be used in an AC circuit with an E_{eff} greater than_________________volts rms.
339.36 240	36. A capacitor has a DCWV of 115 volts. What is the ACWV?
81.3 volts rms (115 x .707)	37. What is meant by the DC working voltage (DCWV) of a capacitor

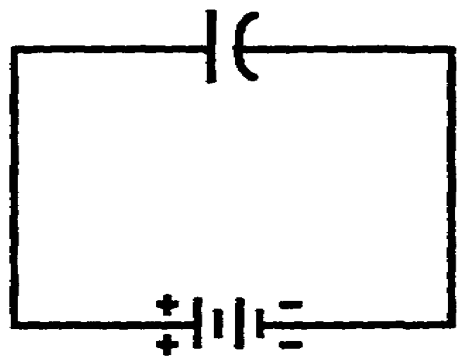
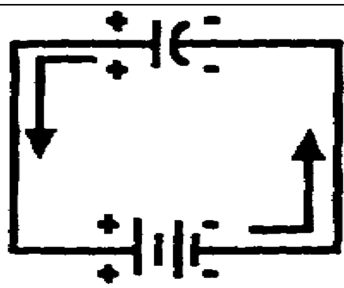
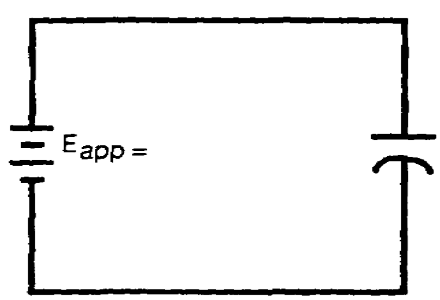
The highest DC voltage that can be safely applied to the contractor.	38.	A capacitor has an ACWV of 115 volts. What is the DCWV?
162.61 volts (115 x 1.414)	39.	Solve for the AC working voltage (ACWV). DCWV = 300 VOLTS. ACWV = ___________________volts rms.
212.1	40.	Solve for the DC working voltage (DCWV). ACWV = 400 volts rms. DCWV = ___________________ volts.
565.6	41.	Capacitors are marked as to type, capacitance, and voltage rating by two methods: (1) Letter-and-number designations. (2) Colored bands and/or dots.  Capacitors may be marked by letter-and-number designations or by ______________________________________.

Colored bands and/or dots	42. **PAPER CAPACITOR**  **Capacity, working voltage, etc., printed on the body of the capacitor.** The two methods of marking capacitors as to type, capacitance, and voltage rating are: (1) Colored bands and/or dots (2) ________________________________
Letter-and-number designations	43. The amount of electrical charge stored in a capacitor depends on: (1) The capacity of the capacitor. (2) The value of the DC voltage across it. The relationship of charge (Q), capacitance (C), and voltage (E) is shown by the basic formula: $Q = CE$ Where: Q = Quantity of charge, in coulombs. C = Capacitance, in farads. E = Applied DC voltage, in volts. Other forms of this formula are: $C = \frac{Q}{E}$ and $E = \frac{Q}{C}$ The basic formula which shows the relationship of charge (0), capacitance (C), and voltage (E) is: (Complete the formula.) Q=

Q = CE	44. The relationship of charge (Q), capacitance (C), and voltage (E) is shown by the basic formula: ______________________________
Q = CE	45. In what two ways are capacitors marked to indicate their capacity and working voltage? (1) (2)
(1) Colored bands and/or dots. (2) Letter-and-number designations.	46. A capacitor can be charged by connecting it across a battery or other DC voltage source as in figure 2.  **Figure 2.** The positive pole of the battery pulls electrons from one plate of the capacitor (A), causing this plate to have a deficiency of electrons (+ charge). The negative pole of the battery forces electrons to flow to the other plate of the capacitor(B), causing this plate to have an excess of electrons(-charge). Electrons flow from the positive(+) plate of the capacitor (arrow A) and to the negative (-) plate of the capacitor (arrow B), until the capacitor is charged to a voltage equal to the applied DC voltage. When a capacitor is connected across a DC voltage source, electrons move out of one plate of the capacitor, making it ____________________, while other electrons flow into the other plate of the capacitor, making it _________________________.

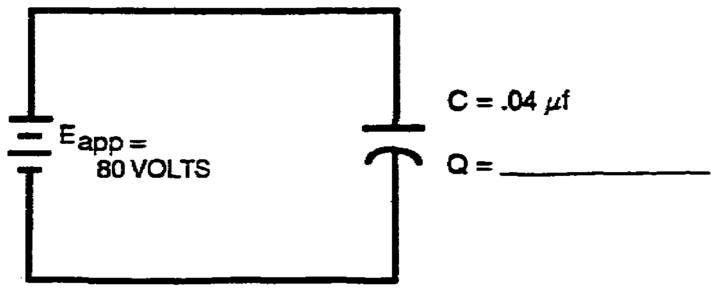
positive negative	47. In figure 3 below, indicate the polarity of the charge on the capacitor. 
 	48. What formula shows the relationship of charge, capacitance, and voltage of a capacitor? FORMULA:
Q = CE	49. In what ways are capacitors marked as to their capacity and working voltage? (1) (2)
(1) Colored bands and/or dots. (2) Letter-and-number designations.	50. By transposing the formula, Q = CE, we can, when given any two values, solve for the third value. $E = \frac{Q}{C}$ To solve for E. Q = 2500 microcoulombs C = 250 microfarads E = ? SOLUTION: $E = \frac{2500 \times 10^{-6}}{250 \times 10^{-6}} = 10$ volts Solve the problem below: Q = 7326 microcoulombs C = 333 μf E = ________________volts

22	51. In the space below, draw a circuit showing a battery and a capacitor connected in series. Indicate, by + and - signs, the polarity of the battery and the polarity of the charge on the capacitor. Indicate, with arrows, the direction of the electron flow (charging current).
	52. What is the formula which shows the relationship between capacitance, charge, and the voltage of a capacitor? FORMULA:
Q = CE	53. As stated previously in the program, the value of a capacitor is the result of the actual physical construction of the capacitor at the time of manufacture $(C = \frac{kA}{d})$. For this reason, we will not solve for the value of a capacitor using the formula $C = \frac{Q}{E}$. Solve for the quantity of charge (Q). C = .10 μf E = 15 volts Q = ________________

1.5 micro- coulombs (Q = CE)	54. Solve the problem below: Q = 525 μ coulomb C = .025 μf E = ________________________volts.
210 $(E = \frac{Q}{C})$	55. Indicate, on the schematic drawing, the direction of the charging current and the polarity of the charge on the capacitor. 
	56. Solve the problem below: C = .025 μf E = 40 volts Q = _________________
1 micro- coulomb (Q = CE)	57. Solve for E_{app}.  C = .02μf Q = 10.4 micro-coulombs E_{app} = _____________volts

520

58. Solve for the quantity of charge on the capacitor.



3.2 micro-coulombs

59. A capacitor, connected across a DC voltage source, will charge almost instantly to the applied voltage.

See fig. 4

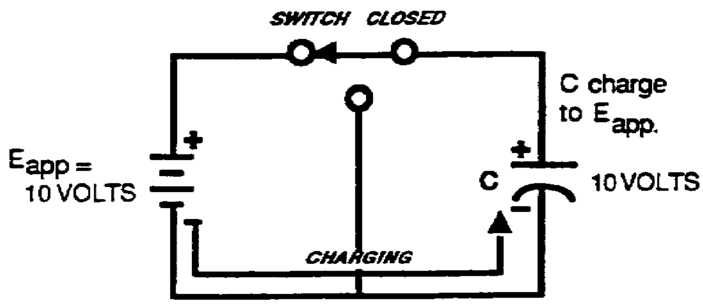


Figure 4.

If we open the switch, removing the source voltage, the capacitor will tend to retain its charge, because it has no discharge path.

See fig. 5.

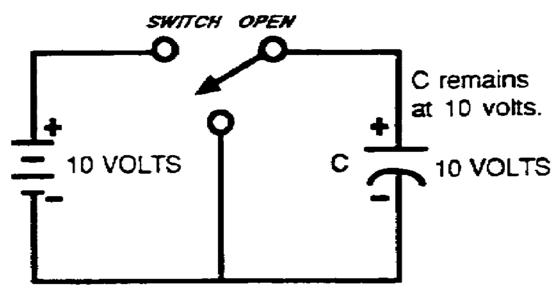


Figure 5.

The charge will remain on the capacitor until a path is provided for it to discharge, at which time it will completely discharge almost instantly.

See fig. 6.

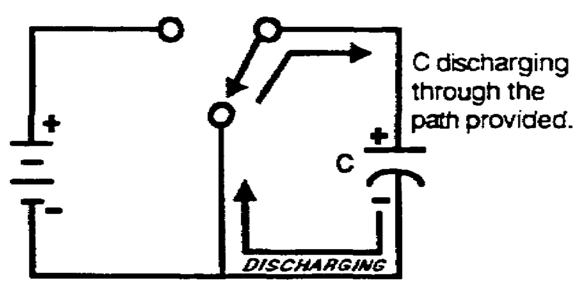
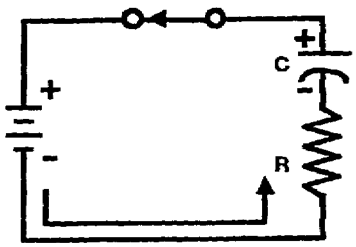


Figure 6.

	60. Fig. 7 represents a series RC circuit, connected across a DC voltage source.  **Figure 7.** The value of R and the value of C determine the RC TIME CONSTANT of the circuit. The RC TIME CONSTANT of any RC circuit is THE TIME THAT IT TAKES A CAPACITOR TO CHANGE ITS CHARGE BY 63%. (Actually 63.2%, but for simplicity and ease of explanation, we use 63%). Since 63% IS a constant, it will hold true regardless of the value of R and C. In an RC circuit, THE TIME THAT IT TAKES A CAPACITOR TO CHANGE ITS CHARGE BY 63% is the ___________________________ of the circuit.
RC time constant	61. If we know the RC TIME CONSTANT of an RC circuit, we know how long it will take the capacitor to change its charge by 63%. The RC TIME CONSTANT of an RC circuit is:

The time it takes a capacitor to change its charge by 63%.	62.	To solve for the RC time constant of any RC circuit is relatively simple, since it is merely a matter of multiplying the value of the resistance times the value of the capacitance. Written as a formula: t = R x C Resistance in ohms multiplied by capacitance in farads equals time in seconds. This is the time it takes the capacitor to change its charge by 63%, and is the RC time constant of the circuit. The RC time constant of an RC circuit is found by the formula: t = ______________ x ______________. This is the time it takes the capacitor to change its charge by_________%.
t = R x C 63%	63.	The formula for computing the RC time constant of an RC circuit is: ______________________________.
t = RC	64.	Explain what is meant by the RC time constant of an RC circuit.
The time it takes a capacitor to change its charge by 63%.	65.	An RC circuit with R of 10 ohms and C of 1 farad has an RC time constant of ________________________. In this circuit, C will change its charge by 63% in______________________.
10 sec. 10 sec.	66.	Solve the following RC problem: R = 470,000 ohms C = .02 μf t = ____________________

9.4 msec or 9400 μsec	67. Write an explanation of what is meant by the "RC time constant" of an RC circuit.
The time it takes a capacitor to change its charge by 63%.	68. In addition to one RC time, which represents the time constant of the circuit (a 63% change) there are three other constants and percentages relative to all RC circuits which must be remembered. They are: (1) In .1 RC time, C changes its charge by 10%. (2) In 2.3 RC time, C changes its charge by 90%. (3) In 10 RC time, C changes its charge by 100%. As with 1 RC time and 63% change, these constants and percentages will hold true for <u>any</u> RC circuit. <u>EXAMPLE</u>: An RC circuit of 10 ohms and 1 farad has an RC time constant of 10 seconds. In one tenth (.1) of the RC time, or 1 second, the capacitor changes its charge by 10%. In 2.3 times the RC time, or 23 seconds, the capacitor changes its charge by 90%. In 10 times the RC time, or 100 seconds, the capacitor changes its charge by 100%. The four common values of RC time and the percentage of capacitor voltage change for each are: (1) .1 RC time - 10% change. (2) 1 RC time =_________________% change. (3) 2.3 RC time =________________% change. (4) 10 RC time =________________% change.
(2) 63 (3) 90 (4) 100	69. List the percentage of capacitor voltage change for each of the RC times below. (1) .1 RC time =______________% change. (2) 1 RC time =______________% change. (3) 2.3 RC time =______________% change. (4) 10 RC time =______________% change.

(1) 10 (2) 63 (3) 90 (4) 100	70. Solve for the RC time constant. R = 69,000 ohms C =.001 μf t = ________________
69 μsec	71. What is the formula used to compute the RC time constant of any RC circuit? FORMULA:
t = RC	72. At this point, we must stress a very important point:

When C is charging, the voltage on C (E_C) plus the voltage across R (E_R) must equal Eapp.

100 volts DC are applied to the RC circuit in fig. 8.

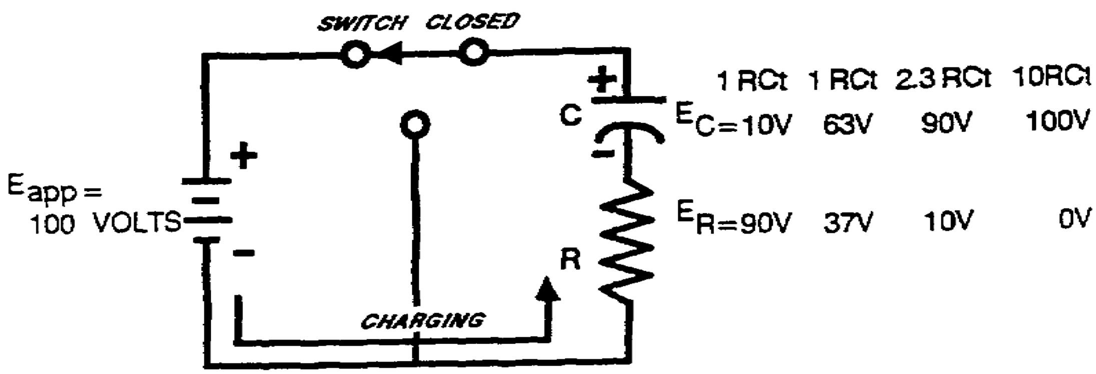


Figure 8.

At the instant the switch is closed, C starts changing.

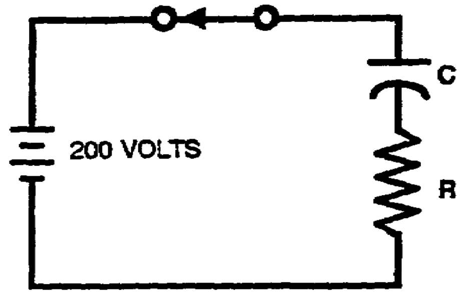
In .1 RC time, E_C = 10 volts and E_R = 90 volts ($E_C + E_R = E_{app}$).

In 1 RC time, E_C = 63 volts and E_R = 37 volts ($E_C + E_R = E_{app}$).

In 2.3 RC time, E_C = 90 volts and E_R = 10 volts ($E_C + E_R = E_{app}$).

In 10 RC time, E_C = 100 volts and E_R = 0 volts ($E_C + E_R = E_{app}$).

With 150 volts applied to an RC circuit for .1 RC time, E_C = 15 volts and E_R = ______________volts.

135	73. In the following problem, what is the value of ER?  E_{app} = 200 volts C charges for 1 RC time. E_C = 126 volts E_R = ______________volts
74	74. Assign the proper value of RC time to each of the percentages of capacitor voltage change listed below. (1) _______________RC time = 90% change. (2) _______________RC time = 10% change. (3) _______________RC time = 100% change. (4) _______________RC time = 63% change.
(1) 2.3 (2) .1 (3) 10 (4) 1	75. Solve for the RC time constant. C = .03 μf R = 220 ohms t = ________________
6. 6μ SEC	

For some students, one of the more difficult things to understand is the capacitor action in an RC circuit during discharge. For the purpose of explanation, we will make a simple comparison.

In a series RC circuit connected across a 100-volt DC source (sw. Pos. A), C will charge to 100 volts (in 10 RC time). Fig. 9.

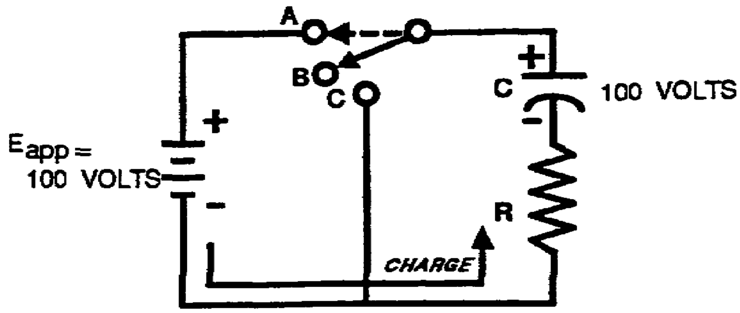


Figure 9.

Remove the source voltage (sw. Pos. B), and C will remain at 100 V until a discharge path is provided.

This can be compared to filling a water tank (representing the capacitor) to a capacity of 100 lbs. of water, with the drain valve closed, and then shutting off the source (fig. 9A).

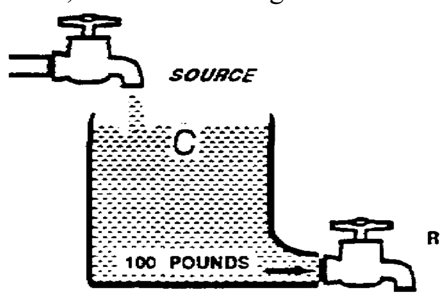


Figure 9A

The water level in the tank (C) remains at 100 lbs of pressure, since there is no outlet (discharge path).

Placing the switch in Pos. C (fig. 9B), provides a discharge path for C.

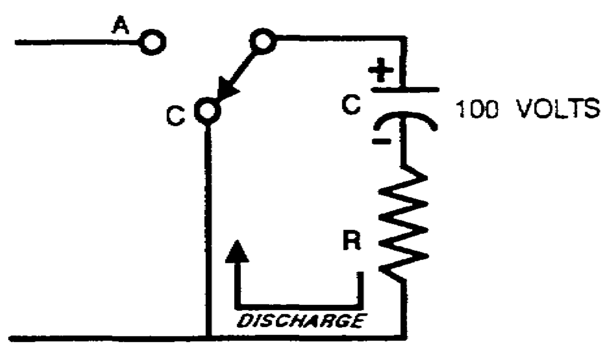


Figure 9B.

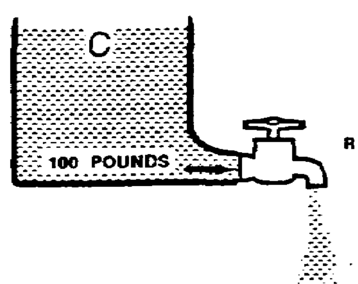


Figure 9C.

This can be compared to opening the valve (fig. 9C) and letting the water start to drain out. (The valve represents R in an RC circuit.)

At the instant the valve (R) is opened, the pressure in the tank (C) is 100 lbs. and the pressure at the valve (R) is 100 lbs. The source of pressure is the water in the tank (C), and this same pressure is developed at the valve (R)).

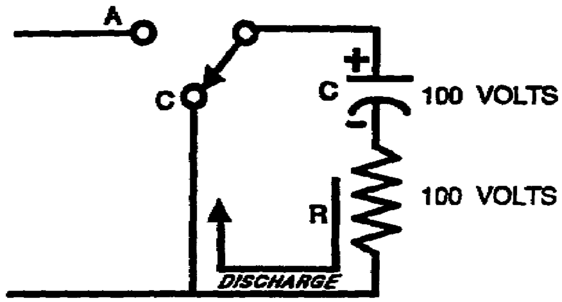


Figure 9D.

In the RC circuit (fig. 9D), at the instant C starts to discharge, the voltage (pressure) on C is 100 volts and the voltage across R (valve) is 100 volts.

The source of voltage (pressure) is the voltage on C, and this same voltage (pressure) is developed across R.

In .1 RC time, C discharges 10%, or 10 volts, which leaves 90 volts on C. THIS SAME 90 VOLTS IS ALSO THE VOLTAGE ACROSS R (fig. 9E).

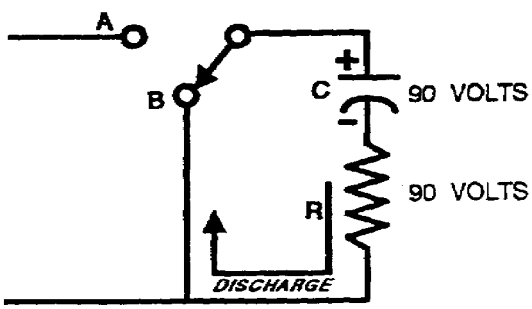


Figure 9E.

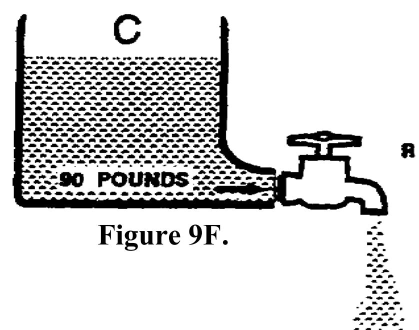


Figure 9F.

This compares with draining 10 lbs. of water pressure from the tank (fig. 9F), which leaves 90 lbs. of pressure in the tank. This same 90 lbs. of pressure is felt at the valve (R).

In 1 RC time, C discharges 63% or 63 volts, which leaves 37 volts on C. THIS 37 VOLTS IS ALSO THE VOLTAGE ACROSS R (fig. 9G).

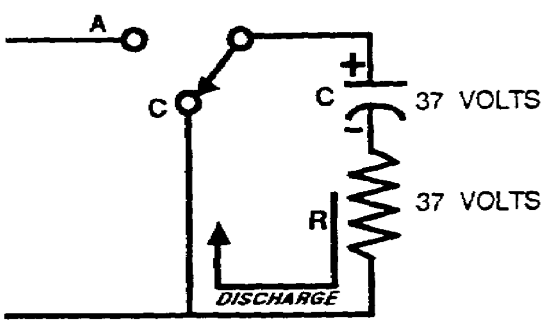


Figure 9G.

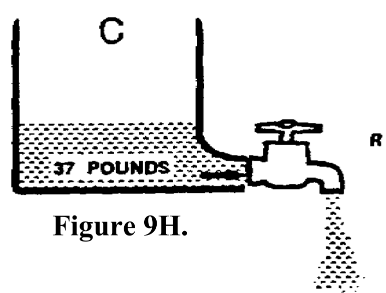
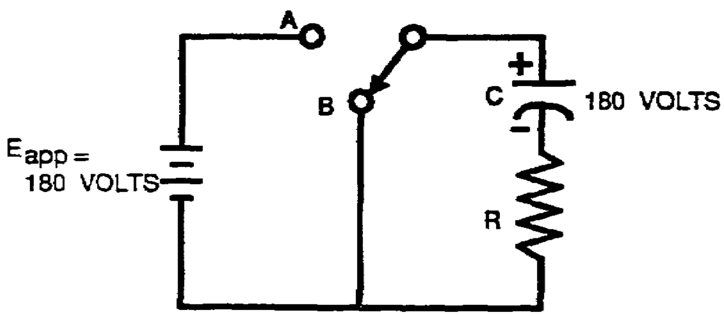
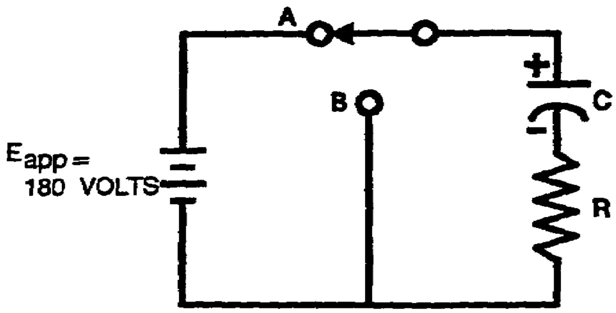
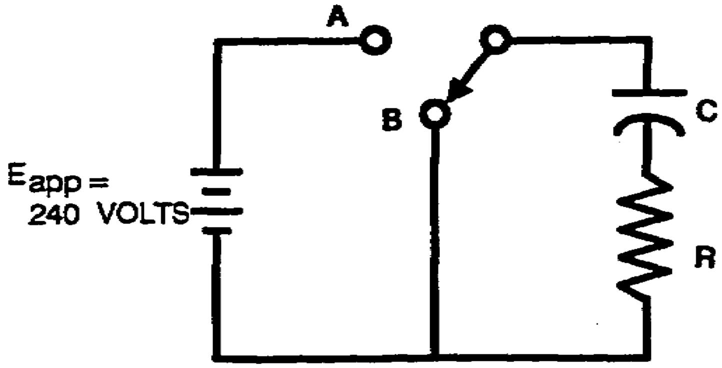
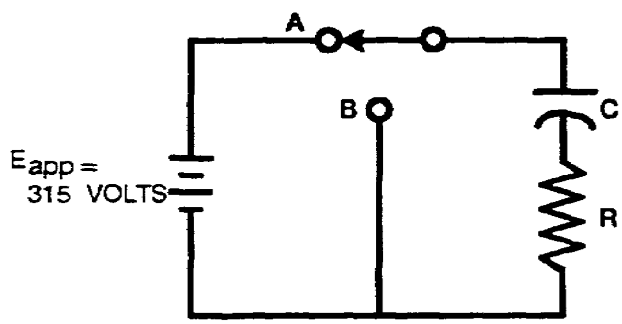


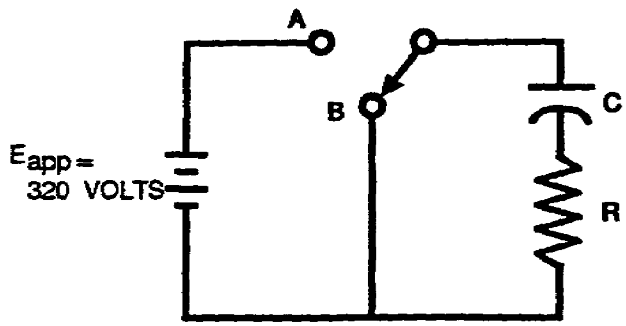
Figure 9H.

This compares with the draining 63 lbs. of water from the tank (fig. 9H) which leaves 37 lbs. of pressure in the tank (C). This 37 lbs. of pressure is felt at the valve (R).

	This process will continue until C is completely discharged (tank is empty) and the voltage is 0 (pressure is 0). Initially, the voltage (pressure) was high and the rate of discharge (draining) was rapid. As the voltage (pressure) decreased, the rate of discharge (draining) decreased. In any RC circuit, when the capacitor is discharging, the voltage across R is the same as the voltage on C. (When C is discharging, $E_R = E_C$.)
No answer required	76. The capacitor in fig. 10 was charged to 180 volts with the switch in Pos. A. The switch is now moved to Pos. B.  **Figure 10.** At the end of 1 RC time, the voltage on the capacitor (E_C) has decreased by______________________%. At 1 RC time, EC = ______________________volts.
63 66.6	77. Referring to fig. 10, at 1 RC time, E_R = ____________________volts. (Hint-when C is discharging, $E_R = E_C$.)

66.6	78. In the following problem, solve for the values of E_C and E_R.  E_{app} = 180 volts C charges for .1 RC time. E_C =________________volts E_R =________________volts
E_C = 18 v E_R = 162v ($E_C + E_R$ = E_{app})	79. List the four common values of RC time and write the percentage of capacitor voltage change for each. (1)______________RC time = _____________% change (2)______________RC time = _____________% change (3)______________RC time = _____________% change (4)______________RC time = _____________% change

(1) .1 10 (2) 1 63 (3) 2.3 90 (4) 10 100	80. Solve for the values of EC and ER.  E_{app} = 240 volts If C is charged to E_{app} then discharged for 1 RC time, E_C =___________________volts E_R =___________________volts
88.8 88.8	81. Solve for the values of EC and ER.  E_{app} = 315 volts C is charges for RC time. E_C =__________________volts E_R =__________________volts

315 0	82. Solve for the values of EC and ER  E_{app} = 320 volts If C is charged to E_{app}, then discharged for 2.3 RC time, E_C =____________________volts E_R =____________________volts
32 32	If you did not get the correct values for both E_C and E_R, it means you forgot that C is DISCHARGING. You must remember that when C is DISCHARGING, $E_R = E_C$.