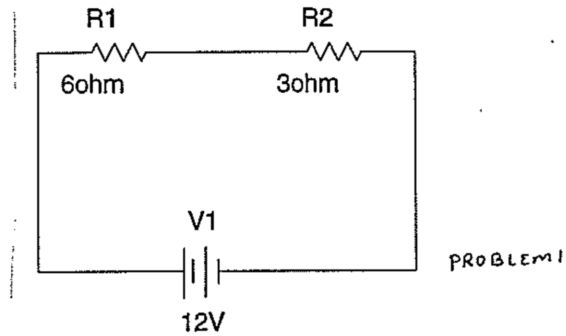
Circuit Analysis

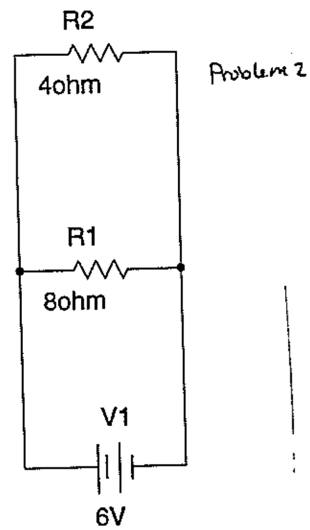
Advanced Placement Physics B
Mr. DiBucci

Name ________________________________ per. ___ Date ________

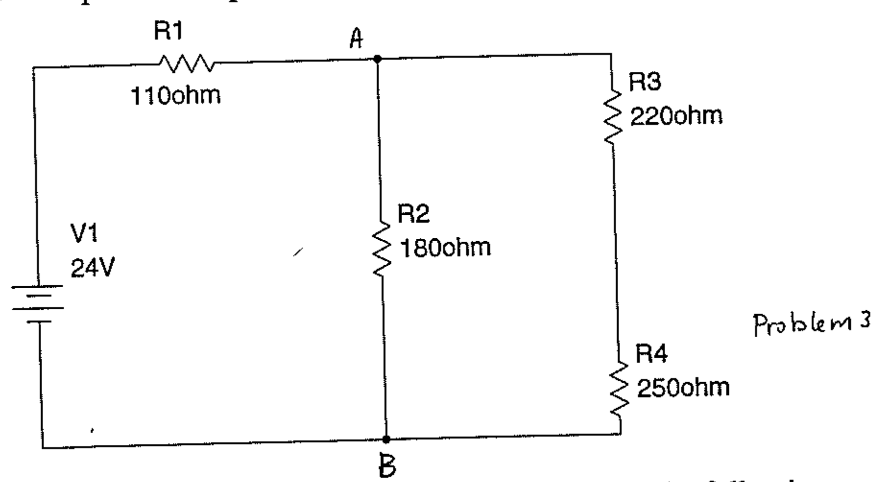
Basic Circuit Analysis DiBucci



1. From the information in the diagram above calculate the following:
a. The equivalent resistance (9.0 ohms)
b. The total current drawn from the battery(1.33 amps)
c. The voltage drop across each resistor(V1=8v, V2=4v)
d. The total power dissipated in this circuit(15.9 Watts)



2. From the information in the diagram above calculate the following:
a. The equivalent resistance(2.67 ohms)
b. The total current drawn from the battery(2.25 amps)
c. The current through each individual resistor(I1=0.750 amps, I2=1.5amps)
d. The total power dissipated in this circuit(13.5 watts)

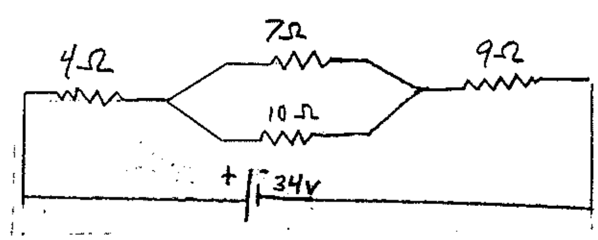


3. From the information in the diagram above calculate the following:
a. The equivalent resistance(240 ohms)
b. The total current drawn from the battery(0.10amps)
c. the potential difference between points A and B(1.3 volts)

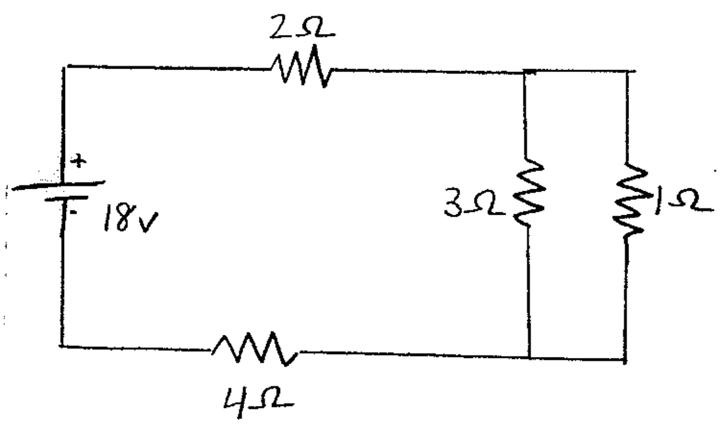
Name ______________________________ per. ___ Date ________

Basic Circuits Practice Worksheet 2

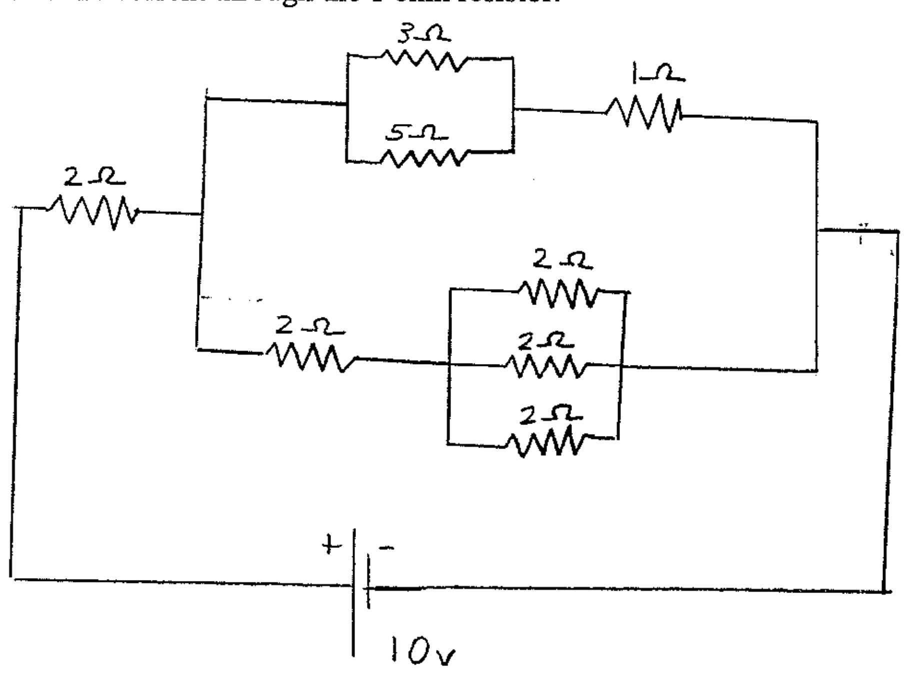
1. Calculate the Equivalent Resistance for this circuit.



2. a. Calculate the equivalent resistance of the circuit.
   b. Calculate the total current being drawn from the battery.
   c. Calculate the power used by the 3 ohm resistor.



2. a. Determine the equivalent resistance for the circuit
   b. Calculate the total current being drawn from the battery.
   c. Calculate the current through the 1 ohm resistor.

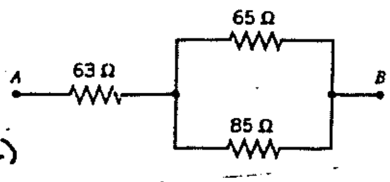


Name ______________________________ per.___ date _____

Electric circuits DiBucci

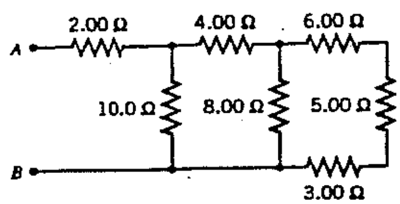
Worksheet 1

1) **ssm** For the combination of resistors shown in the drawing, determine the equivalent resistance between points *A* and *B*.



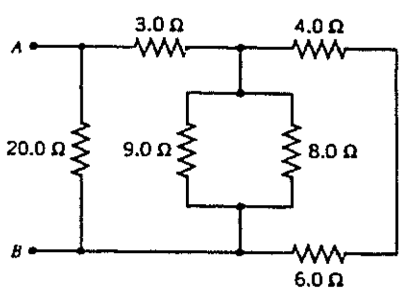
(100 Ω)

2) Find the equivalent resistance between points *A* and *B* in the drawing.



(6.67 Ω)

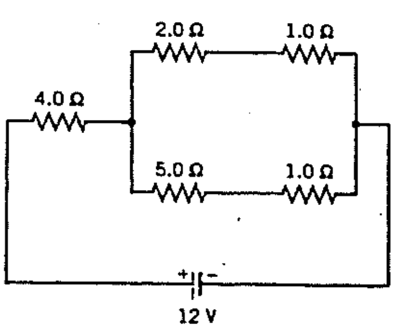
3) **ssm** Determine the equivalent resistance between the points *A* and *B* for the group of resistors in the drawing.



(4.6 Ω)

4) Determine the power dissipated in the 5.0-Ω resistor in the circuit shown in the drawing.

(2.2 W)



Superconductivity

We have seen that normal materials have electric resistance, which leads to power loss and heating. Many electrical applications require materials with very low resistance—the lower the better. Power transmission lines, electromagnets, computer chips—all would be revolutionized by resistanceless materials. In fact, under special conditions, materials with zero resistance do exist; but making practical use of them continues to be a difficult problem.

In 1908 the Dutch physicist H. Kamerlingh Onnes (1853-1926) succeeded in liquefying helium, for which he received the 1913 Nobel Prize in physics. At atmospheric pressure, helium liquefies at 4.2 K. Moreover, when the pressure above liquid helium is reduced, its temperature can be lowered to below 1 K.

Physics in Practice

It was well known at that time that the electric resistance of metals decreases with decreasing temperature, approaching a limiting, or residual, value as the temperature approaches zero. However, in 1911, when Kamerlingh Onnes cooled mercury to temperatures below 4 K, its resistance suddenly dropped to zero at a particular transition temperature T_c (Fig. B18.1). This loss of resistance occurred even when the mercury was impure. Kamerlingh Onnes realized that the mercury had undergone a phase transition to a new state and had become a *superconductor*. In this new superconducting state, the resistance of the mercury was truly zero.

In the years that followed, many other materials were identified as superconductors, including aluminum (T_c = [illegible] K), lead ($T_c = 7.2$ K), niobium ($T_c = 9.3$ K), and a number of intermetallic compounds such as niobium-tin (Nb_3Sn, $T_c = 18$ K). Materials such as niobium-tin have been used for the current-carrying windings of superconducting magnets for research and medicine. Magnets of this type are capable of very large magnetic fields. However, to keep them cold (so that they are below their transition temperature), they must be well insulated and cooled with liquid helium.

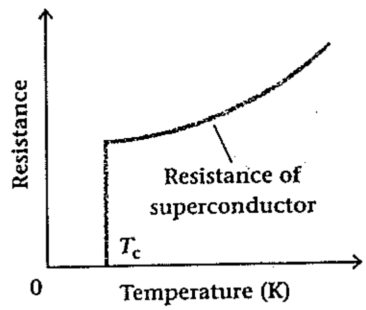
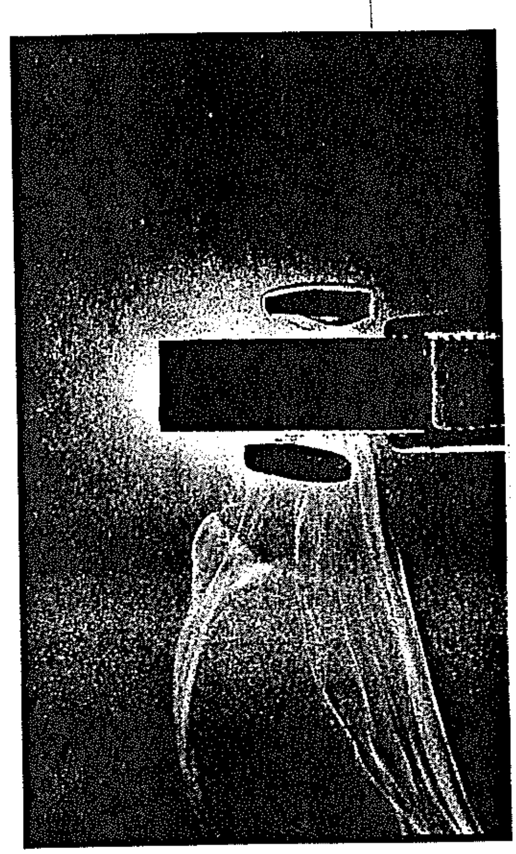


Figure B18.1 The resistance of a superconductor suddenly drops to zero as its temperature is lowered through the superconducting transition temperature, T_c.

Because of the expense and difficulty of using liquid helium as a coolant, many researchers sought superconductors with higher transition temperatures. In particular, they sought superconductors with transition temperatures above 77 K, which is the boiling point of liquid nitrogen, a relatively inexpensive coolant. For many years, the highest known superconducting transition temperature was 23 K, the transition temperature of niobium-germanium (Nb_3Ge). However, in 1986 J. G. Bednorz and K. A. Müller of the IBM Zurich laboratory found an oxide compound of barium, lanthanum, and copper that became superconducting at 35 K. This discovery earned them the 1987 Nobel Prize in physics, and it set off a wave of activity in laboratories around the world by investigators searching for materials with even higher transition temperatures. By 1988, superconductors with transition temperatures as high as 125 K had been reported (Fig. B18.2). In spite of intensive efforts, no higher transition temperatures had been observed by early 1992.

Because the new high-temperature superconductors require relatively inexpensive coolants, they hold promise for a wide range of applications. Possibilities include electric power transmission without resistive losses, new magnets, and perhaps even magnetically levitated vehicles. However, these applications require improved materials because the available high-temperature superconductors lose their superconductivity when carrying large currents.

Figure B18.2 Two small magnets, one above and one below, are held in place by a high-temperature superconductor cooled below its superconducting transition temperature.



Electric shock is a hazard associated with all electric appliances and equipment. The danger of electrocution is not just for the high voltages of transmission lines. Unfortunately, people have been killed by ordinary house current at 120 V or by contact with industrial equipment at 40 or 50 V.

The important measure of shock intensity is not the voltage, but the amount of current that passes through the body (Fig. B18.3). Thus any electric device using ordinary household voltages can potentially supply a fatal current. The amount of current can be determined from Ohm's law, but since the body's electric resistance varies enormously, it is not possible to give precise statements of safe or dangerous voltages. For example, the body's effective resistance depends largely upon the area of contact and the condition of the skin. But skin resistance may vary from about 500,000 Ω dry to as little as 500 Ω when wet.

The hazards of electric shock depend not only on the amount of current involved, but also on the path of the current. A current passing through your arm from fingertip to elbow may produce a painful and unpleasant shock, but the same current passing from one hand to the other through your chest may be fatal.

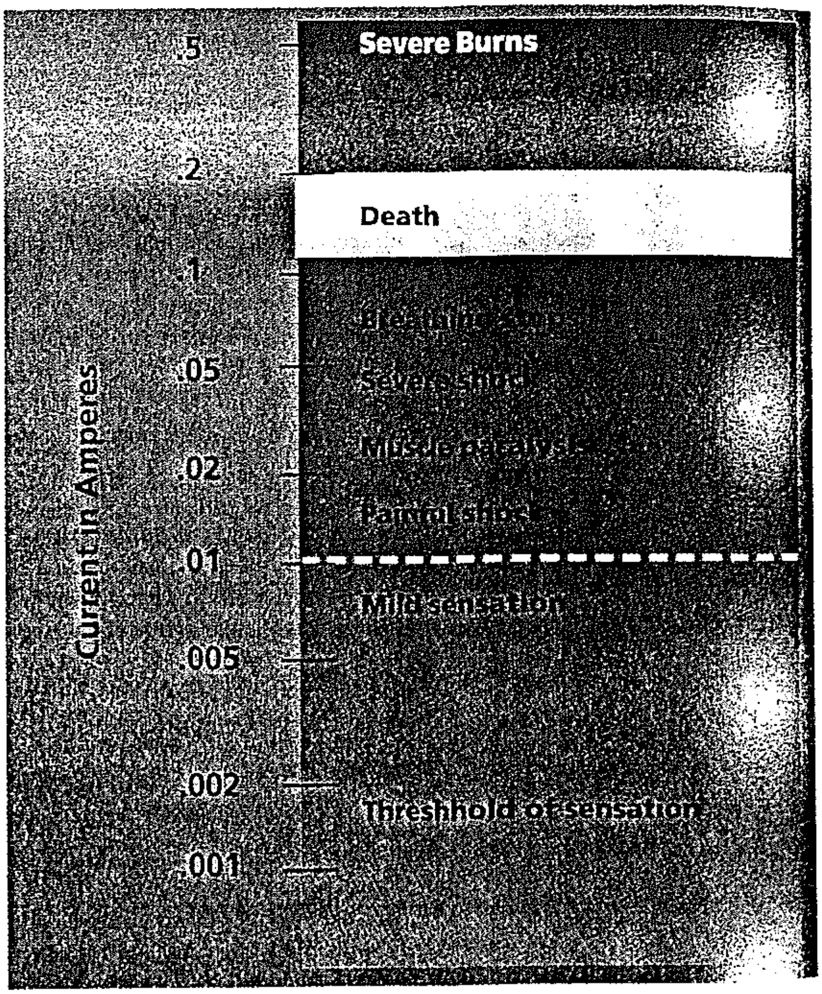
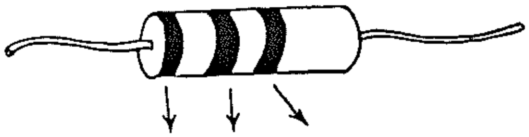


Figure B18.3 Electrical shock hazard at various values of current.

Electric current can damage the body in three distinct ways: (1) it may subject the body to intense heat and cause burns; (2) it may disrupt the proper functioning of the nervous system and heart; and (3) it may cause the muscles to twitch uncontrollably. Currents as low as 20 mA may cause difficulty in breathing, and at 75 mA breathing may stop completely. Currents between about 100 and 200 mA result in ventricular fibrillation of the heart, which means an uncoordinated and uncontrolled twitching of the heart muscles. The resulting loss of pumping action is fatal. At still greater currents, the heart may stop completely without going into fibrillation. Under such conditions, the chance of survival may actually be improved, since the heartbeat can be more easily restored from being stopped than from fibrillation. The defibrillators used in medical emergencies apply a large momentary voltage to the body to stop the heart and facilitate the restoration of the normal heart rhythm.

The best medicine for electric shock is prevention. Have respect for electricity at all voltages. Be cautious and follow normal safety procedures when working with electrical equipment.

RESISTOR COLOR CODE



BLACK	0	0	× 1
BROWN	1	1	× 10
RED	2	2	× 100
ORANGE	3	3	× 1,000
YELLOW	4	4	× 10,000
GREEN	5	5	× 100,000
BLUE	6	6	× 1,000,000
VIOLET	7	7	× 10,000,000
GRAY	8	8	× 100,000,000
WHITE	9	9	

FOURTH BAND INDICATES TOLERANCE (ACCURACY):
GOLD = ± 5 %   SILVER = ± 10 %   NONE = ± 20 %

OHM'S LAW:

$V = IR$ $R = V/I$
$I = V/R$ $P = VI = I^2R$

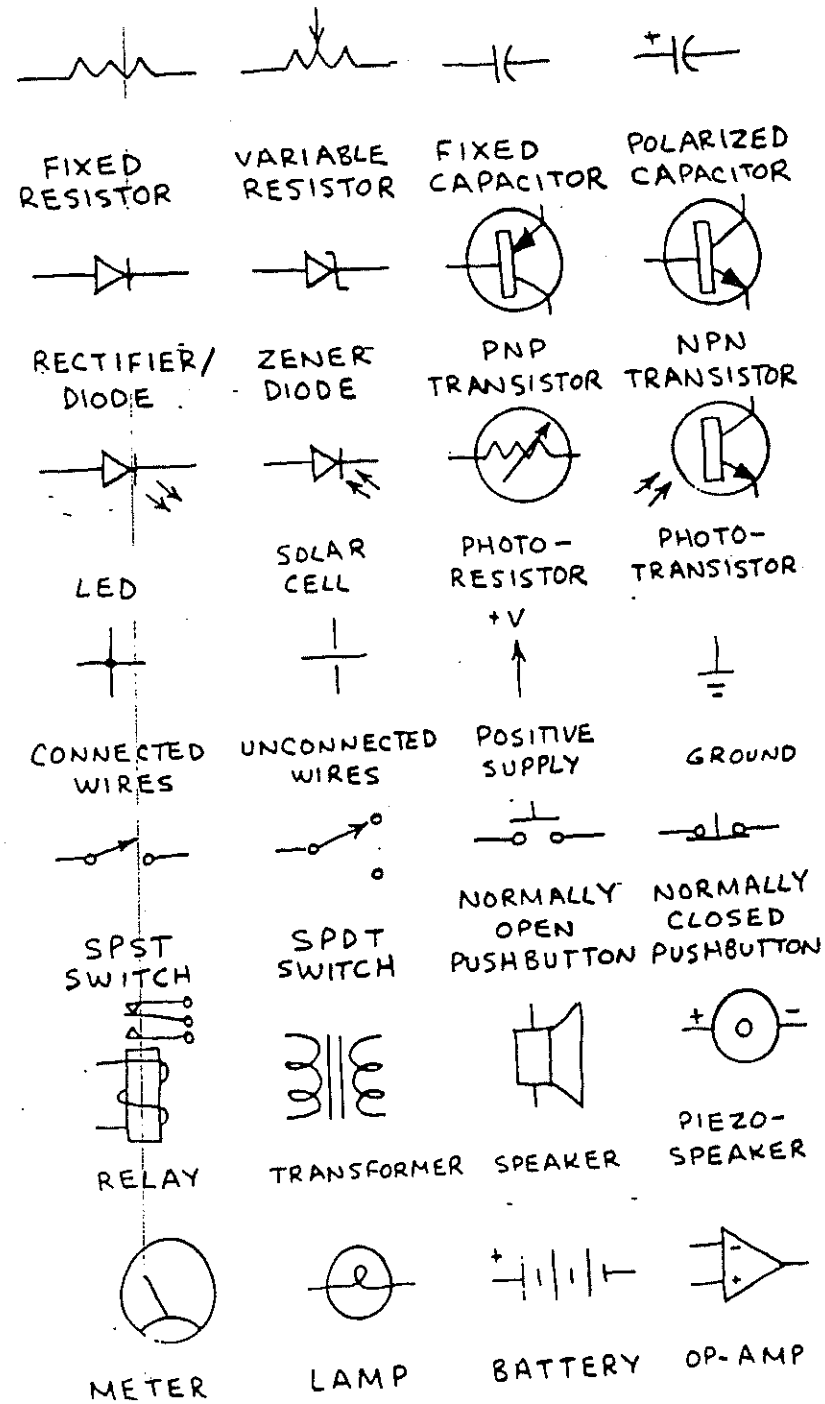
ABBREVIATIONS

A = AMPERE
F = FARAD
I = CURRENT
P = POWER

R = RESISTANCE
V (OR E) = VOLT
W = WATT
Ω = OHM

M (MEG-) = × 1,000,000
K (KILO-) = × 1,000
m (MILLI-) = .001
μ (MICRO-) = .000 001
n (NANO-) = .000 000 001
p (PICO-) = .000 000 000 001

CIRCUIT SYMBOLS



ection 20.1 Electromotive Force and Current,
ection 20.2 Ohm's Law

1. **ssm** A portable compact disc player is designed to play for 2.0 h on a fully charged battery pack. If the battery pack provides a total of 180 C of charge, how much current does the player use in operating?

2. A CD-ROM drive in a laptop computer uses a current of 0.27 A. In one minute, how many electrons pass through the device?

3. A toaster has a resistance of 14 Ω and is plugged into a 120-V outlet. What is the current in the toaster?

4. The filament of a light bulb has a resistance of 580 Ω. A voltage of 120 V is connected across the filament. How much current in the filament?

5. **ssm** In the arctic, electric socks are useful. A pair of socks uses a 9.0-V battery pack for each sock. A current of 0.11 A is drawn from each battery pack by wire woven into the socks. Find the resistance of the wire in one sock.

6. A battery charger is connected to a dead battery and delivers a current of 6.0 A for 5.0 hours, keeping the voltage across the battery terminals at 12 V in the process. How much energy is delivered to the battery?

7. A car battery has a rating of 220 ampere · hours (A · h). This rating is one indication of the *total charge* that the battery can provide to a circuit before failing. (a) What is the total charge (in coulombs) that this battery can provide? (b) Determine the maximum current that the battery can provide for 38 minutes.

*8. The resistance of a bagel toaster is 14 Ω. To prepare a bagel, the toaster is operated for one minute from a 120-V outlet. How much energy is delivered to the toaster?

9. **ssm A beam of protons is moving toward a target in a particle accelerator. This beam constitutes a current whose value is 0.50 μA. (a) How many protons strike the target in 15 seconds? (b) Each proton has a kinetic energy of 4.9×10^{-12} J. Suppose the target is a 15-gram block of aluminum, and all the kinetic energy of the protons goes into heating it up. What is the change in temperature of the block at the end of 15 s?

Section 20.3 Resistance and Resistivity

10. High-voltage power lines are a familiar sight throughout the country. The aluminum wire used for some of these lines has a cross-sectional area of 4.9×10^{-4} m^2. What is the resistance of ten kilometers of this wire?

11. A coil of wire has a resistance of 38.0 Ω at 25 °C and 43.7 Ω at 55 °C. What is the temperature coefficient of resistivity?

12. The filament in an incandescent light bulb is made from tungsten. The radius of the tungsten wire is 0.045 mm. If the bulb is to be plugged into a 120-V outlet and is to draw a current of 1.24 A, how long must the wire be?

13. **ssm** **www** Two wires have the same length and the same resistance. One is made from aluminum and the other from copper. Obtain the ratio of the cross-sectional area of the aluminum wire to that of the copper wire.

DiBucci
ElectroDynamics
Home work

1) 0.25A
2) 1×10^{20}
3) 8.6A
4) 0.21A
5) 82Ω
6) 1.3×10^{6} J
7) 7.9×10^{5} C
350A
8) 6.2×10^{4} J
9) 4.7×10^{13}, B) skip
10) 0.58Ω
11) 0.0050 (°C)$^{-1}$
12) 11 m
13) 1.64

14. An aluminum wire has a cross-sectional area of $7.9 \times 10^{-7}\ m^2$. Find the resistance *per unit length* for this wire.

15. A cylindrical copper cable carries a current of 1200 A. There is a potential difference of 1.6×10^{-2} V between two points on the cable that are 0.24 m apart. What is the radius of the cable?

16. In Section 12.3 it was mentioned that temperatures are often measured with electrical resistance thermometers made of platinum wire. Suppose that the resistance of a platinum resistance thermometer is 125 Ω when its temperature is 20.0 °C. The wire is then immersed in boiling chlorine, and the resistance drops to 99.6 Ω. The temperature coefficient of resistivity of platinum is $\alpha = 3.72 \times 10^{-3}\ (C°)^{-1}$. What is the temperature of the boiling chlorine?

***17.** **ssm www** A wire has a resistance of 21.0 Ω. It is melted down, and from the same volume of metal a new wire is made that is three times longer than the original wire. What is the resistance of the new wire?

***18.** A gold wire and a silver wire have the same resistance and the same volume. Find the ratio (gold/silver) of the radii of the wires.

***19.** A toaster uses a Nichrome heating wire. When the toaster is turned on at 20 °C, the initial current is 1.50 A. A few seconds later, the toaster warms up and the current has a value of 1.30 A. The average temperature coefficient of resistivity for Nichrome wire is $4.5 \times 10^{-4}\ (C°)^{-1}$. What is the temperature of the heating wire?

***20.** An iron wire has a resistance of 5.90 Ω at 20.0 °C, and a gold wire has a resistance of 6.70 Ω at the same temperature. The temperature coefficient of resistivity for iron is $0.0050\ (C°)^{-1}$, while for gold it is $0.0034\ (C°)^{-1}$. At what temperature do the wires have the same resistance?

****21.** **ssm www** Two wires have the same cross-sectional area and are joined end to end to form a single wire. One is tungsten, which has a temperature coefficient of resistivity of $\alpha = 0.0045\ (C°)^{-1}$. The other is carbon, for which $\alpha = -0.0005\ (C°)^{-1}$. The total resistance of the composite wire is the sum of the resistances of the pieces. The total resistance of the composite does *not change with temperature*. What is the ratio of the lengths of the tungsten and carbon sections? Ignore any changes in length due to thermal expansion.

Section 20.4 Electric Power

22. An automobile battery is being charged at a voltage of 12.0 V and a current of 19.0 A. How much power is being produced by the charger?

23. The heating element in an iron has a resistance of 24 Ω. The toaster is plugged into a 120-V outlet. What is the power dissipated by the iron?

24. An electric blanket is connected to a 120-V outlet and consumes 140 W of power. What is the current in the wire in the blanket?

14) $3.6 \times 10^{-2}\ \frac{\Omega}{m}$

15) 9.9×10^{-3} m

16) −34.6 °C

17) 189 Ω

18) 1.11

19) 360 °C

20) 140 °C

21) 70

22) 228 W

23) 6.0×10^{2} W

24) 1.2 A

25. **ssm** In doing a load of clothes, a clothes drier uses 16 A of current at 240 V for 45 min. A personal computer, in contrast, uses 2.7 A of current at 120 V. With the energy used by the clothes drier, how long (in hours) could you use this computer to "surf" the internet?

26. An electric alarm clock uses a 5.0-W motor and runs all day every day. If electricity costs \$0.10/kWh, determine the yearly cost of running the clock.

27. A commercial resistor can safely dissipate power only up to a certain rated value. Beyond this value, the resistor becomes excessively hot and often cracks apart. What is the largest voltage that can be applied across a 680-Ω resistor, when the resistor is rated at (a) 0.25 W and (b) 2.0 W?

*28. A piece of Nichrome wire has a radius of 6.5×10^{-4} m. It is used in a laboratory to make a heater that dissipates 4.00×10^{2} W of power when connected to a voltage source of 120 V. Ignoring the effect of temperature on resistance, estimate the necessary length of wire.

*29. **ssm** Tungsten has a temperature coefficient of resistivity of 0.0045 $(C°)^{-1}$. A tungsten wire is connected to a source of constant voltage via a switch. At the instant the switch is closed, the temperature of the wire is 28 °C, and the initial power dissipated in the wire is P_0. At what wire temperature has the power dissipated in the wire decreased to $\frac{1}{2}P_0$?

**30. An iron wire has a resistance of 12 Ω at 20.0 °C and a mass of 1.3×10^{-3} kg. A current of 0.10 A is sent through the wire for one minute and causes the wire to become hot. Assuming that all the electrical energy is dissipated in the wire and remains there, find the final temperature of the wire. (*Hint: Use the average resistance of the wire during the heating process, and see Table 12.2 for the specific heat capacity of iron. Note* $\alpha = 0.0050\ (C°)^{-1}$.)

25) 8.9 hours
26) \$4.4
27) 13 V, 37 V
28) 50 m
29) 250°C
30) 33°C

Section 20.6 Series Wiring

40. The current in a 47-Ω resistor is 0.12 A. This resistor is in series with a 28-Ω resistor, and the series combination is connected across a battery. What is the battery voltage?

41. **ssm** Three resistors, 25, 45, and 75 Ω, are connected in series, and a 0.51-A current passes through them. What is (a) the equivalent resistance and (b) the potential difference across the three resistors?

42. A 36.0-Ω resistor and an 18.0-Ω resistor are connected in series across a 15.0-V battery. What is the voltage across (a) the 36.0-Ω resistor and (b) the 18.0-Ω resistor?

43. A battery dissipates 2.50 W of power in each of two 47.0-Ω resistors connected in series. What is the voltage of the battery?

44. Three resistors, 9.0, 5.0, and 1.0 Ω, are connected in series across a 24-V battery. Find (a) the current in, (b) the voltage across, and (c) the power dissipated in each resistor.

45. **ssm** The current in a series circuit is 15.0 A. When an additional 8.00-Ω resistor is inserted in series, the current drops to 12.0 A. What is the resistance in the original circuit?

46. Two cylindrical rods, one copper and the other iron, are identical in lengths and cross-sectional areas. They are joined, end-to-end, to form one long rod. A 12-V battery is connected across the free ends of the copper–iron rod. What is the voltage between the ends of the copper rod?

47. Three resistors are connected in series across a battery. The value of each resistance and its maximum power rating are as follows: 5.0 Ω and 20.0 W, 30.0 Ω and 10.0 W, and 15.0 Ω and 10.0 W. (a) What is the greatest voltage that the battery can have without one of the resistors burning up? (b) How much power does the battery deliver to the circuit in (a)?

48. Two resistances, R_1 and R_2, are connected in series across a 12-V battery. The current increases by 0.20 A when R_2 is removed, leaving R_1 connected across the battery. However, the current increases by just 0.10 A when R_1 is removed, leaving R_2 connected across the battery. Find (a) R_1 and (b) R_2.

40) 9.0 v
41) 145 Ω, 74 v
42) 10 v, 5 v
43) 21.7 v
44) 1.6 A, 14 v, 8 V, 1.6 V, 23 W 13 W, 2.6 W
45) 32 Ω
46) 1.8 V
47) 28.9 V, 16.7 w
48) 35 Ω, 50 Ω

Section 20.7 Parallel Wiring

49. ssm A 16-Ω loudspeaker and an 8.0-Ω loudspeaker are connected in parallel across the terminals of an amplifier. Assuming the speakers behave as resistors, determine the equivalent resistance of the two speakers.

50. What resistance must be placed in parallel with a 155-Ω resistor to make the equivalent resistance 115 Ω?

51. How many 4.0-Ω resistors must be connected in parallel to create an equivalent resistance of one-sixteenth of an ohm?

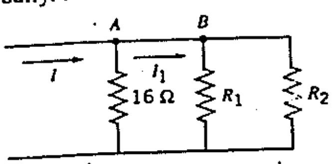
52. A wire whose resistance is R is cut into three equally long pieces, which are then connected in parallel. In terms of R, what is the resistance of the parallel combination?

53. ssm Two resistors, 42.0 and 64.0 Ω, are connected in parallel. The current through the 64.0-Ω resistor is 3.00 A. (a) Determine the current in the other resistor. (b) What is the total power consumed by the two resistors?

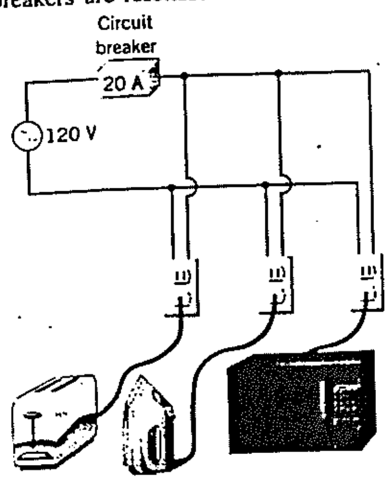
54. For the 3-way bulb (50 W, 100 W, 150 W) discussed in Conceptual Example 10, find the resistance of each of the two filaments. Assume that the wattage ratings are not limited by significant figures and ignore any heating effects on the resistances.

55. A coffee cup heater and a lamp are connected in parallel to the same 120-V outlet. Together, they use a total of 84 W of power. The resistance of the heater is 6.0×10^{2} Ω. Find the resistance of the lamp.

56. The drawing shows three resistors connected in parallel. At junction A the current I divides equally. At junction B the current I_1 also divides equally. Find the values of (a) R_1 and (b) R_2.



***57. ssm** The total current delivered to a number of devices connected in parallel is the sum of the individual currents in each device. Circuit breakers are resettable automatic switches that protect against a dangerously large total current by "opening" to stop the current at a specified safe value. A 1650-W toaster, a 1090-W iron, and a 1250-W microwave oven are turned on in a kitchen. As the drawing shows, they are all connected through a 20-A circuit breaker to an ac voltage of 120 V. (a) Find the equivalent resistance of the three devices. (b) Obtain the total current delivered by the source and determine whether the breaker will "open" to prevent an accident.



49) 5.3Ω
50) 446Ω
51) 64
52) R/9
53) 4.57A, 1450W
54) 288Ω, 144Ω
55) 240Ω
56) 32Ω, 32Ω
57) 3.6Ω; 33A

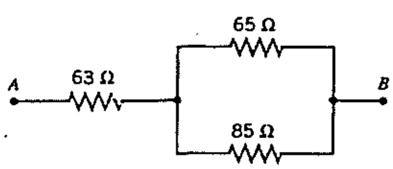
60) 9.2 A
) 100Ω
62) 930Ω
63) 6.76Ω
64) 8.33×10^{-2} A
0.833 W
65) 4.6Ω
66) 300Ω

67) 2.2 W
68) 600Ω
69) 0.750 A
2.11 A

Section 20.8 Circuits Wired Partially in Series and Partially in Parallel

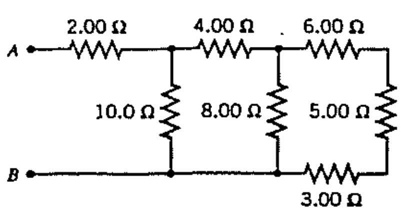
60. A 14-Ω coffee maker and a 16-Ω frying pan are connected in series across a 120-V source of voltage. A 23-Ω bread maker is also connected across the 120-V source and is in parallel with the series combination. Find the total current supplied by the source of voltage.

61. **ssm** For the combination of resistors shown in the drawing, determine the equivalent resistance between points *A* and *B*.



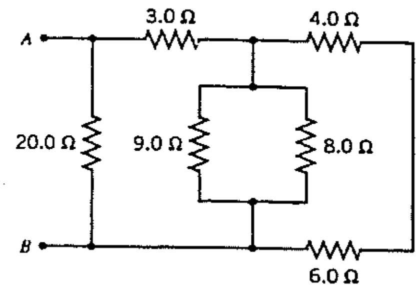
62. Circuit *A* has three resistors connected in series (R_1 = 30 Ω, R_2 = 70 Ω, and R_3 = 210 Ω). Circuit *B* has three resistors (different from any of those in circuit *A*) connected in parallel. In circuit *B* each resistor has the same resistance. What is the resistance of each resistor in circuit *B*, such that the equivalent resistance of *B* equals the equivalent resistance of *A*?

63. Find the equivalent resistance between points *A* and *B* in the drawing.



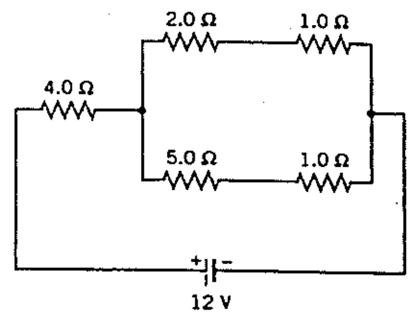
64. A 60.0-Ω resistor is connected in parallel with a 120.0-Ω resistor. This parallel group is connected in series with a 20.0-Ω resistor. The total combination is connected across a 15.0-V battery. Find (a) the current and (b) the power dissipated in the 120.0-Ω resistor.

65. **ssm** Determine the equivalent resistance between the points *A* and *B* for the group of resistors in the drawing.



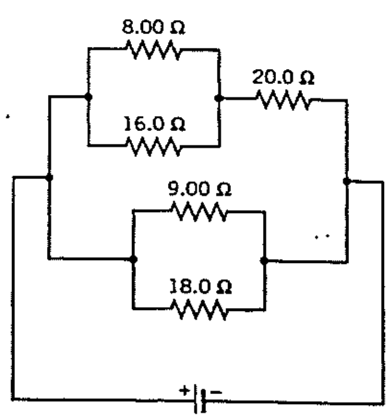
***66.** You have a number of identical 450.0-Ω resistors. (a) There is one way in which three of these resistors can be wired to give an equivalent resistance of 300.0 Ω. What is it? (b) There are two ways in which six of these resistors can be wired to give an equivalent resistance of 300.0 Ω. What are they? In both parts (a) and (b), show calculations to support your answers.

***67.** Determine the power dissipated in the 5.0-Ω resistor in the circuit shown in the drawing.



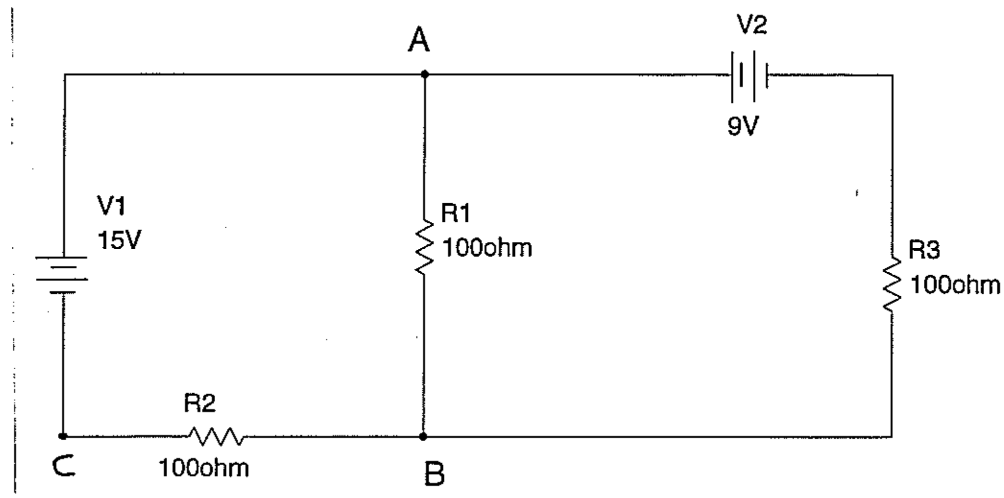
***68.** Three identical resistors are connected in parallel. The equivalent resistance increases by 700 Ω when one resistor is removed and connected in series with the remaining two, which are still in parallel. Find the resistance of each resistor.

****69.** **ssm www** The current in the 8.00-Ω resistor in the drawing is 0.500 A. Find the current in (a) the 20.0-Ω resistor and in (b) the 9.00-Ω resistor.



Name ______________________________ **per.** ___ **Date** ________
Electrodynamics **DiBucci**

Kirchhoff's Rules for Circuit Analysis

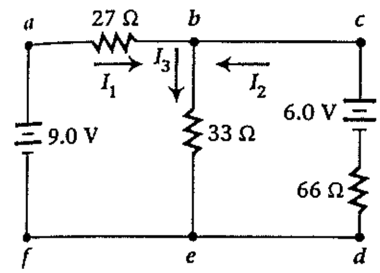


Consider the diagram above.

a. Use Kirchhoff's rules for circuit analysis to determine the current through each resistor.
b. Calculate the potential difference between points A&B, and A&D.

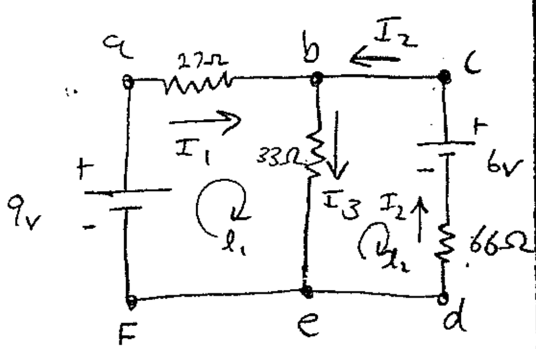
Name____ per. ___ Date ____
Electrodynamics *DiBucci*

Kirchhoff's Rules for Circuit Analysis: Practice Problem



a. Calculate the currents I1, I2, and I3 as labeled in the diagram above.
b. Calculate the voltage between points a and d, and indicate which is at the higher potential.

Solution



Part a

$J_B \Rightarrow \quad I_1 + I_2 = I_3$

$l_1 \Rightarrow \quad +9 - 27I_1 - 33I_3 = 0$

$l_2 \Rightarrow \quad -6 + 66I_2 + 33I_3 = 0$

Sub in

$$\begin{cases} l_1: & 9 - 27I_1 - 33I_3 = 0 \\ l_2: & -6 + 66I_2 + 33I_3 = 0 \end{cases} \qquad \left\{ J_B: \ I_1 = \boxed{I_3 - I_2} \right.$$

$$\begin{cases} 9 - 27(I_3 - I_2) - 33I_3 = 0 \\ -6 + 66I_2 + 33I_3 = 0 \end{cases}$$

$$\begin{cases} 9 - 27I_3 + 27I_2 - 33I_3 = 0 \\ -6 + 66I_2 + 33I_3 = 0 \end{cases}$$ collect like terms

$$\begin{cases} [9 + 27I_2 - 60I_3 = 0] \times (33) \\ [-6 + 66I_2 + 33I_3 = 0] \times (+60) \end{cases}$$ eliminate I_3

$$\begin{cases} +297 + 891I_2 - 1980I_3 = 0 \\ -360 + 3960I_2 + 1980I_3 = 0 \end{cases}$$

+ equations

$-63 + 4851I_2 = 0$

$I_2 = \frac{63}{4851} = \boxed{0.013\,A}$

From $l_2 \Rightarrow \quad -6 + 66(0.013A) + 33I_3 = 0$

$-5.14 + 33I_3 = 0$

$I_3 = \frac{5.14}{33}$

$\boxed{I_3 \ 0.16A}$

From J_B: $I_1 + I_2 = I_3$

$I_1 = I_3 - I_2$

$I_1 = 0.16A - 0.013A$

$I_1 \boxed{= 0.147A}$

Alternate matrix method for part a

$1I_1 + 1I_2 - 1I_3 = 0$

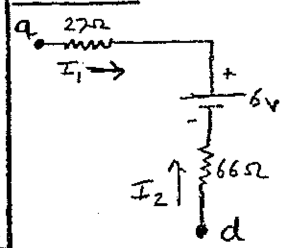
$-27I_1 + 0I_2 - 33I_3 = -9$

$0I_1 + 66I_2 + 33I_3 = +6$

let $A = \begin{bmatrix} 1 & 1 & -1 \\ -27 & 0 & -33 \\ 0 & 66 & 33 \end{bmatrix} \quad B = \begin{bmatrix} 0 \\ -9 \\ 6 \end{bmatrix}$

Then $X = \begin{bmatrix} 0.14A \\ 0.013A \\ 0.16A \end{bmatrix} \begin{matrix} I_1 \\ I_2 \\ I_3 \end{matrix}$

Part B



$V_a - 27I_1 - 6 + 66I_2 = V_d$

$V_d - V_A =$

$= -27(.14A) - 6 + 66(0.013)$

$= -9.11V$

$V_d - V_A = -9.11V$

$\therefore V_A > V_d$

*Name*____ *Per.*___ *date.* __________

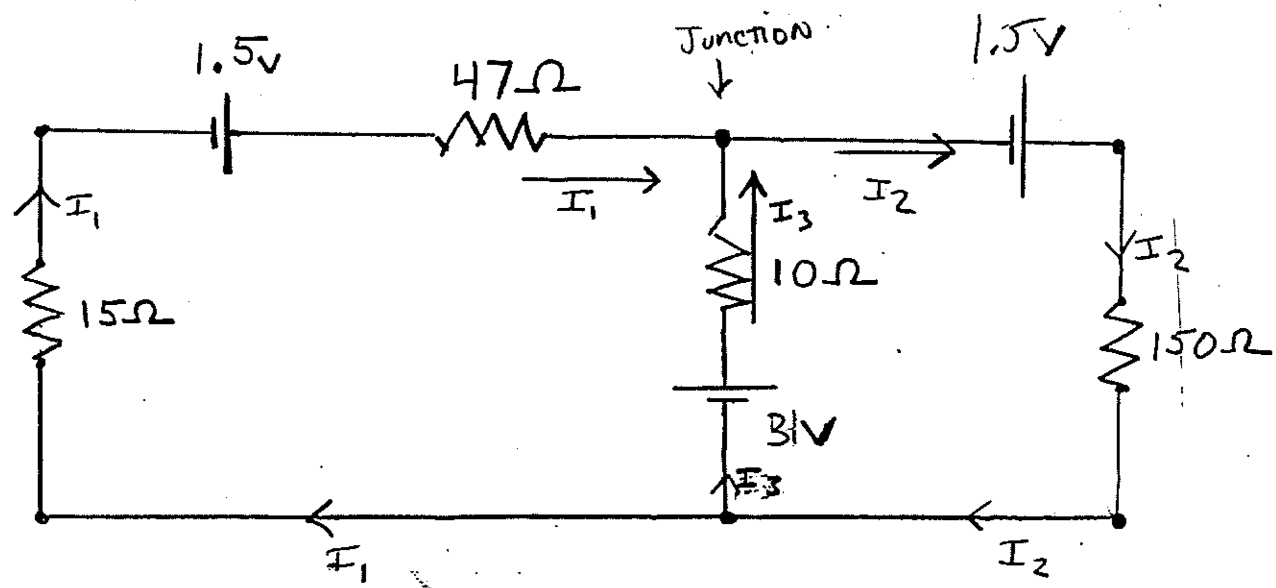
Kirchhoff's Rules for Circuit Analysis ***DiBucci***

Objective: Apply Kirchhoff's Rules of circuit analysis to calculate various unknown quantities in a Circuit.

Loop Rule:

Junction Rule:

Use Kirchhoff's rules of circuit analysis to calculate I1, I2, and I3 in the circuit below



Solution to Kirchhoff's Rules
DIBUCCI

23

$I_1 + I_3 = I_2$ ③

$$\begin{cases} -15I_1 + 1.5 - 47I_1 + 10I_3 - 3V = 0 & ④ \\ +3 - 10I_3 + 1.5 - 150I_2 = 0 & ④ \end{cases}$$

$$\begin{cases} -62I_1 + 10I_3 - 1.5V = 0 \\ -150I_2 - 10I_3 + 4.5 = 0 \end{cases}$$

$$\begin{cases} -62I_1 + 10I_3 - 1.5 = 0 \\ -150I_1 - 150I_3 - 10I_3 + 4.5 = 0 \end{cases}$$ sub ③

$$\begin{cases} (-62I_1 + 10I_3 - 1.5 = 0)16 \\ -150I_1 - 160I_3 + 4.5 = 0 \end{cases}$$

$-992I_1 + 160I_3 - 24 = 0$

$-150I_1 - 160I_3 + 4.5 = 0$

$-1142I_1 - 19.5 = 0$

$I_1 = \frac{19.5}{-1142} = -.017A$ ③

$-62(-.017) + 10(I_3) - 1.5 = 0$

$+1.054 + 10I_3 - 1.5 = 0$

$10I_3 = .0446$

$I_3 = .0446\,A$ ③

$I_2 = .0276$ ③

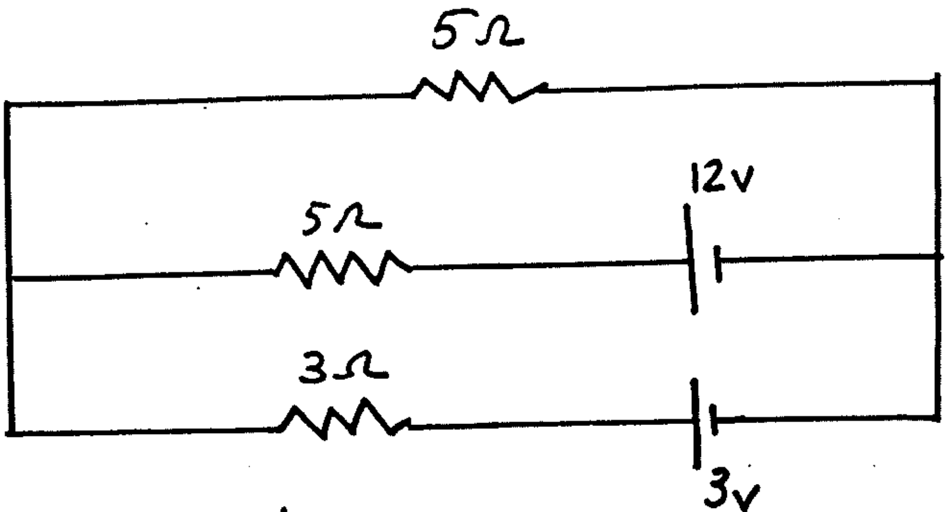
B.) $V_{ab} =$

$V_B - V_A = 1.5 - 47I_1$

$= 1.5 - 47(0.017A)$

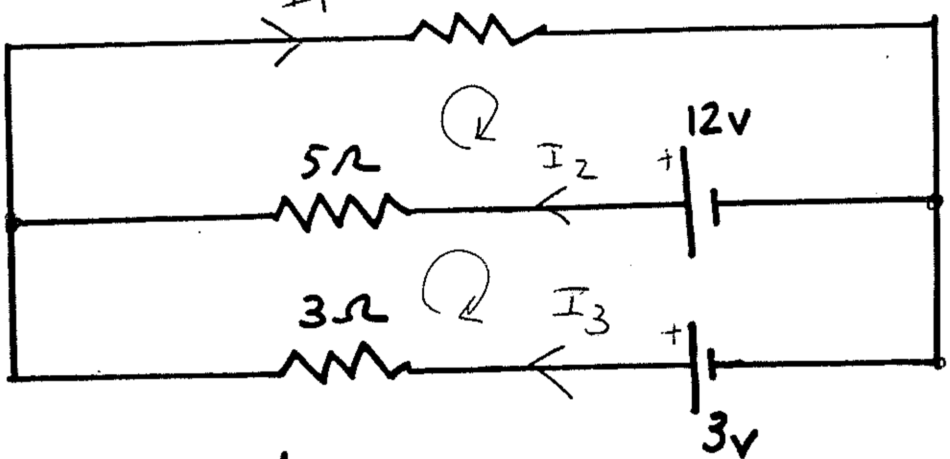
$= +2.3V$

3.



* Calculate the current in the 3 ohm Resistor
(use Kirchhoff's Rules)

3.



* Calculate the current in the 3 ohm Resistor (use kirchhoff's Rules)

$$\begin{cases} 3 - 3I_3 + 5I_2 - 12 = 0 \\ 12 - 5I_2 - 5I_1 = 0 \end{cases}$$

$$I_2 + I_3 = I_1$$

$$\begin{cases} -9 - 3I_3 + 5I_2 = 0 \\ 12 - 5I_2 - 5I_1 = 0 \end{cases}$$

$$\begin{cases} -9 - 3I_3 + 5I_2 = 0 \\ 12 - 5I_2 - 5[I_2 + I_3] = 0 \end{cases}$$

$$\begin{cases} -9 - 3I_3 + 5I_2 = 0 \\ +12 - 5I_2 - 5I_2 - 5I_3 = 0 \end{cases}$$

$$\begin{cases} (-9 - 3I_3 + 5I_2 = 0)2 \\ +12 - 5I_3 - 10I_2 = 0 \end{cases}$$

$$\begin{cases} -18 - 6I_3 + 10I_2 = 0 \\ +12 - 5I_3 - 10I_2 = 0 \end{cases}$$

$$-6 - 11I_3 = 0$$

$$-11I_3 = 6$$

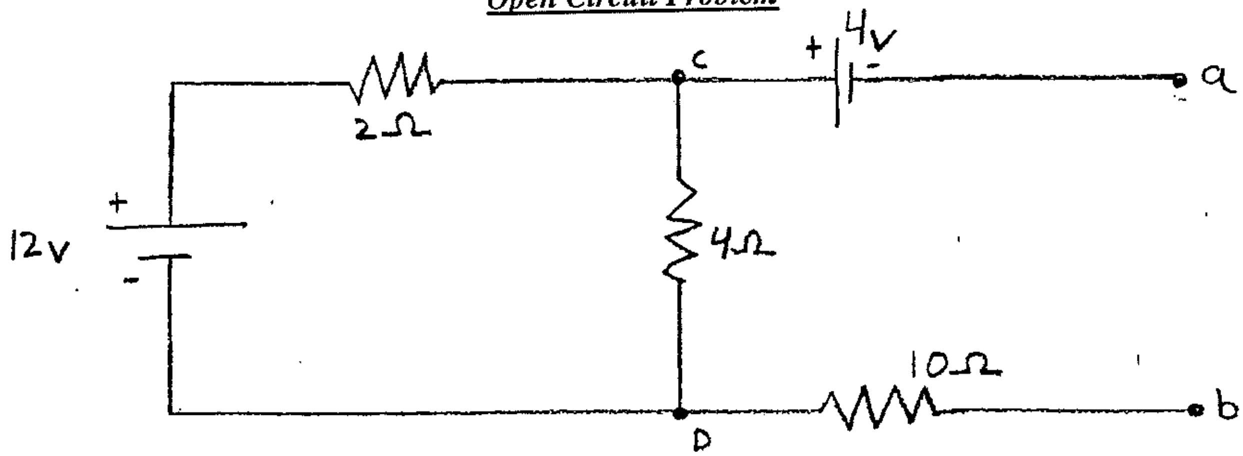
$$I_3 = \frac{6}{-11}$$

$$\boxed{I_3 = -.55A}$$

∴ $I_3 = .55$ to the Rt.

*Name*____ *per.* ___ *Date* ____
Electrodynamics *DiBucci*

Open Circuit Problem



Calculate the voltage between points a and b, and indicate which is at the higher potential.

INTERNAL RESISTANCE

So far, the circuits we have considered include batteries or generators that add only their emfs to a circuit. In reality, however, such devices also add some resistance. This resistance is called the ***internal resistance*** of the battery or generator, because it is located inside the device. In a battery, the internal resistance is due to the chemicals within the battery. In a generator, the internal resistance is the resistance of wires and other components in the generator.

Figure 20.25 shows a schematic representation of the internal resistance r of a battery. The drawing emphasizes that when an external resistance R is connected to the battery, the resistance is connected *in series* with the internal resistance. The internal resistance of a functioning battery is typically small (several thousandths of an ohm for a new car battery). Nevertheless, the effect of the internal resistance may not be negligible. Example 12 illustrates that when current is drawn from a battery, the internal resistance causes the voltage between the terminals to drop below the maximum value specified by the battery's emf. The actual voltage between the terminals of a battery is known as the ***terminal voltage.***

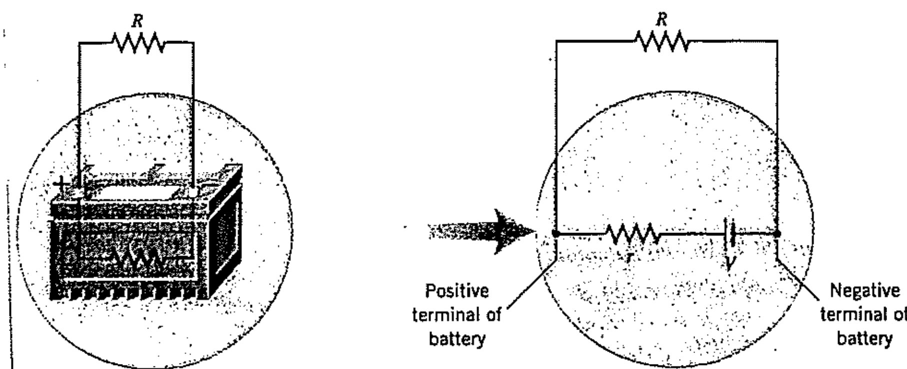


Figure 20.25 When an external resistance R is connected between the terminals of a battery, the resistance is connected in series with the internal resistance r of the battery.

EXAMPLE 12 • The Terminal Voltage of a Battery

Figure 20.26 shows a car battery whose emf is 12.0 V and whose internal resistance is 0.010 Ω. This resistance is relatively large because the battery is old and the terminals are corroded. What is the terminal voltage when the current I drawn from the battery is (a) 10.0 A and (b) 100.0 A?

Reasoning The voltage between the terminals is not the entire 12.0-V emf, because part of the emf is needed to make the current go through the internal resistance. The amount of voltage needed can be determined from Ohm's law as the current I through the battery times the internal resistance r. For larger currents, a larger amount of voltage is needed, leaving less of the emf between the terminals of the battery.

Solution

(a) The amount of voltage needed to make a current of $I = 10.0$ A go through an internal resistance of $r = 0.010\ \Omega$ is $V = Ir = (10.0\text{ A})(0.010\ \Omega) = 0.10$ V. To find the terminal voltage, remember that the direction of conventional current is always from a higher potential toward a lower potential. To emphasize this fact in the drawing, plus and minus signs have been included at the right and left ends, respectively, of the resistance r. The terminal voltage can be calculated by starting at the negative terminal of the battery and keeping track of how the voltage increases and decreases as we move toward the positive terminal. The voltage rises by 12.0 V due to the battery's emf. However, the voltage drops by 0.10 V because of the potential difference across the internal resistance. Therefore, the terminal voltage is 12.0 V − 0.10 V = $\boxed{11.9\text{ V}}$.

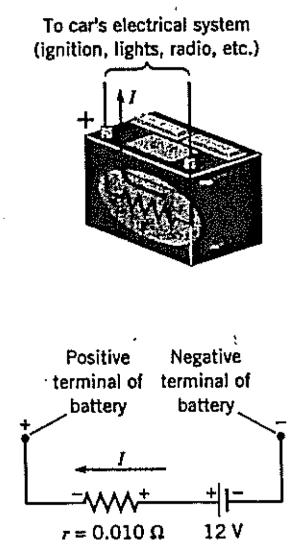


Figure 20.26 A car battery whose emf is 12 V and whose internal resistance is r.

(b) When the current through the battery is 100.0 A, the amount of voltage needed to make the current go through the internal resistance is $V = (100.0\text{ A})(0.010\ \Omega) = 1.0\text{ V}$. The terminal voltage of the battery now decreases to $12.0\text{ V} - 1.0\text{ V} = \boxed{11.0\text{ V}}$.

Example 12 indicates that the terminal voltage of a battery is smaller when the current drawn from the battery is larger, an effect that any car owner can demonstrate. Turn the headlights on before starting your car, so the current through the battery is about 10 A, as in part (a) of Example 12. Then start the car. The starter motor draws a large amount of additional current from the battery, momentarily increasing the total current by an appreciable amount. Consequently, the terminal voltage of the battery decreases, causing the headlights to dim.

70) 10.9V
71) 0.054Ω
72) 0.12Ω
73) 30
74) 0.907
75) 0.054

Section 20.9 Internal Resistance

70. A battery has an emf of 12.0 V and an internal resistance of 0.15 Ω. What is the terminal voltage when the battery is connected to a 1.50-Ω resistor?

71. A new "D" battery has an emf of 1.5 V. When a wire of negligible resistance is connected between the terminals of the battery, a current of 28 A is produced. Find the internal resistance of the battery.

72. A 1.40-Ω resistor is connected across a 9.00-V battery. The voltage between the terminals of the battery is observed to be only 8.30 V. Find the internal resistance of the battery.

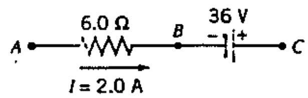
73. **ssm** A battery has an internal resistance of 0.50 Ω. A number of identical light bulbs, each with a resistance of 15 Ω, are connected in parallel across the battery terminals. The terminal voltage of the battery is observed to be one-half the emf of the battery. How many bulbs are connected?

74. A 1.20-Ω resistor is connected across a battery. If the battery had no internal resistance, the power dissipated in the resistor would be P_0. However, the battery does have an internal resistance of 0.060 Ω, so that the power dissipated in the 1.20-Ω resistor is P instead of P_0. Find the ratio P/P_0.

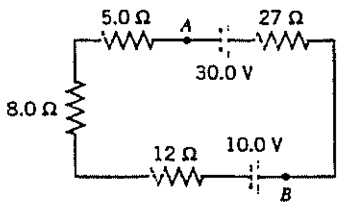
***75.** A resistor has a resistance R, and a battery has an internal resistance r. When the resistor is connected across the battery, ten percent less power is dissipated in R than there would be if the battery had no internal resistance. Find the ratio r/R.

Section 20.10 Kirchhoff's Rules

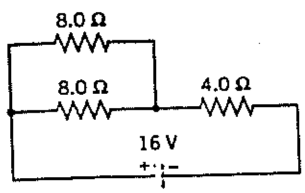
76. A current of 2.0 A exists in the partial circuit shown in the drawing. What is the magnitude of the potential difference between the points (a) A and B, and (b) A and C?



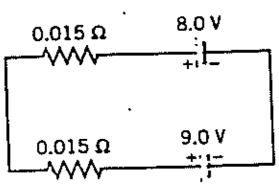
77. ssm Consider the circuit in the drawing. Determine (a) the magnitude of the current in the circuit and (b) the magnitude of the voltage between the points labeled A and B. (c) State which point, A or B, is at the higher potential.



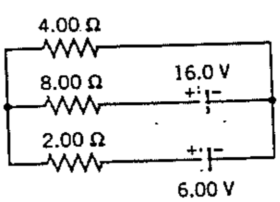
78. The drawing shows resistors that are partly in series and partly in parallel. (a) Find the current in the 4.0-Ω resistor without using Kirchhoff's rules. (b) Redetermine the current in the 4.0-Ω resistor, this time using Kirchhoff's rules. Verify that the answer obtained is the same as that in part (a).



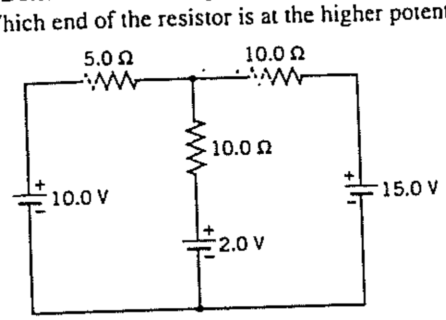
79. Two batteries, each with an internal resistance of 0.015 Ω, are connected as in the drawing. In effect, the 9.0-V battery is being used to charge the 8.0-V battery. What is the current in the circuit?



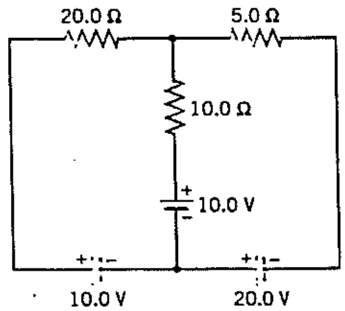
80. For the circuit shown in the drawing, find the current in the 8.00-Ω resistor. Be sure to specify the direction of the current.



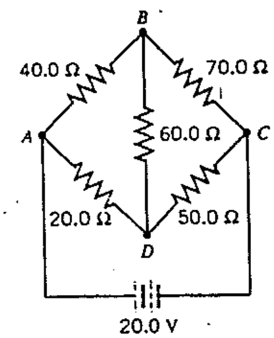
***81. ssm** Determine the voltage across the 5.0-Ω resistor in the drawing. Which end of the resistor is at the higher potential?



***82.** For the circuit in the drawing, find the current in the 10.0-Ω resistor. Specify the direction of the current.



****83.** The circuit in the drawing is known as a Wheatstone bridge circuit. Find the voltage between points B and D, and state which point is at the higher potential.



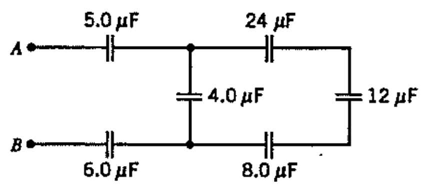
76) 12V, 24V
77) 0.38A, 20V
78) 2A, 2A
79) 33A
80) 1.29A Right to left
81) 0.75V, left of resistor
82) 1.71 A
83) 0.94V D is higher potential

Section 20.12 Capacitors in Series and Parallel

90. A 2.00-μF and a 4.00-μF capacitor are connected to a 60.0-V battery. How much charge is supplied by the battery in charging the capacitors when the wiring is (a) in parallel and (b) in series?

91. A 4.0-μF and an 8.0-μF capacitor are connected in parallel across a 25-V battery. Find (a) the equivalent capacitance and (b) the total charge stored on the two capacitors.

92. Determine the equivalent capacitance between A and B for the group of capacitors in the drawing.



93. **ssm** A 3.0-μF capacitor and a 4.0-μF capacitor are connected in series across a 40.0-V battery. A 10.0-μF capacitor is also connected directly across the battery terminals. Find the total charge that the battery delivers to the capacitors.

94. Three capacitors (4.0, 6.0, and 12.0 μF) are connected in series across a 50.0-V battery. Find the voltage across the 4.0-μF capacitor.

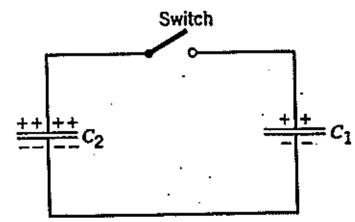
95. Three capacitors have identical geometries. One is filled with a material whose dielectric constant is 2.50. Another is filled with a material whose dielectric constant is 4.00. The third capacitor is filled with a material whose dielectric constant κ is such that this single capacitor has the same capacitance as the series combination of the other two. Determine κ.

96. Suppose two capacitors (C_1 and C_2) are connected in series. Show that the sum of the energies stored in these capacitors is equal to the energy stored in the equivalent capacitor. *[Hint: The energy stored in a capacitor can be expressed as $q^2/(2C)$.]*

***97.** **ssm** A 7.0-μF and a 3.0-μF capacitor are connected in series across a 24-V battery. What voltage is required to charge a parallel combination of the two capacitors to the same total energy?

***98.** A 3.00-μF and a 5.00-μF capacitor are connected in series across a 30.0-V battery. A 7.00-μF capacitor is then connected in parallel across the 3.00-μF capacitor. Determine the voltage across the 7.00-μF capacitor.

****99.** The drawing shows two fully charged capacitors ($C_1 = 2.00$ μF, $q_1 = 6.00$ μC; $C_2 = 8.00$ μF, $q_2 = 12.0$ μC). The switch is closed, and charge flows until equilibrium is reestablished (i.e., until both capacitors have the same voltage across their plates). Find the resulting voltage across either capacitor.



90) 3.6×10^{-6} C, 8×10^{-5} C

91) 12.0 μF, 3.0×10^{-4} V

92) 2.0 μF

93) 4.96×10^{-4} C

94) 25V

95) 1.54

96) $Q^2/2C$

97) 11V

98) 10V

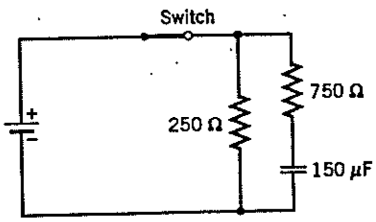
99) 1.80V

Section 20.13 *RC* Circuits

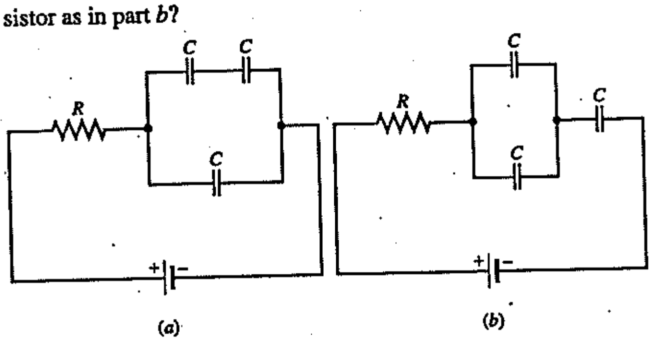
100. An electronic flash attachment for a camera produces a flash by using the energy stored in a 750-μF capacitor. Between flashes, the capacitor recharges through a resistor whose resistance is chosen so the capacitor recharges with a time constant of 3.0 s. Determine the value of the resistance.

101. ssm In a heart pacemaker, a pulse is delivered to the heart 81 times per minute. The capacitor that controls this pulsing rate discharges through a resistance of $1.8 \times 10^6\ \Omega$. One pulse is delivered every time the fully charged capacitor loses 63.2% of its original charge. What is the capacitance of the capacitor?

102. The 150-μF capacitor in the drawing is fully charged. When the switch is opened, the capacitor begins to discharge. What is the time constant for the discharge?



***103.** Three identical capacitors are connected with a resistor in two different ways. When they are connected as in part *a* of the drawing, the time constant to charge up this circuit is 0.34 s. What is the time constant when they are connected with the same resistor as in part *b*?



****104.** How many time constants must elapse before a capacitor in a series *RC* circuit is charged to within 0.10% of its equilibrium charge?

100) $4.0 \times 10^3\ \Omega$

101) 4.1×10^{-7} F

102) 0.15 s

103) 0.15 s.

104) 6.9

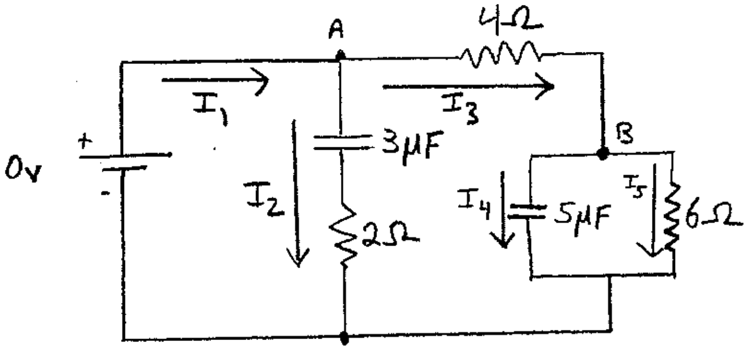
Name________________________________ per.___ Date________

AP Physics B

DiBucci

Resistor – Capacitor (RC) Circuits

1. Refer to the diagram below. For the initial state, calculate the current in each branch of the circuit, the voltage across each capacitor and the energy stored in each capacitor. Repeat this for the Steady State.



Initial

$I_1 = 15A$ $\mathcal{E}_3 = 0J$

$I_2 = 10A$ $\mathcal{E}_5 = 0J$

$I_3 = 5A$

$I_4 = 5A$

$I_5 = 0A$

$V_{3\mu F} = 0v$

$V_{5\mu F} = 0v$

STEADY STATE

$I_1 = 2A$ $\mathcal{E}_{3\mu F} = 6\times10^{-4}J$

$I_2 = 0$ $\mathcal{E}_{5\mu F} = 3.6\times10^{-4}J$

$I_3 = 2A$

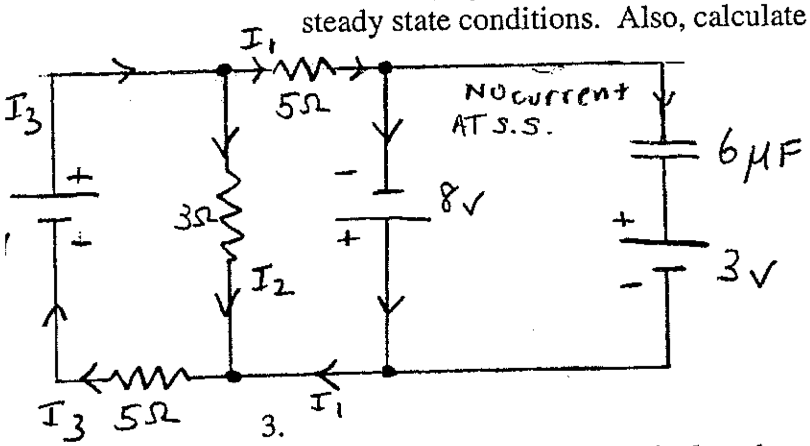
$I_4 = 0A$

$I_5 = 2A$

$V_{3\mu F} = 20V$

$V_{5\mu F} = 12V$

2. From the diagram below calculate the current in each branch of the circuit under steady state conditions. Also, calculate the charge on the capacitor.



$I_1 = 1.38A$

$I_2 = -0.364A$

$I_3 = 1.02A$

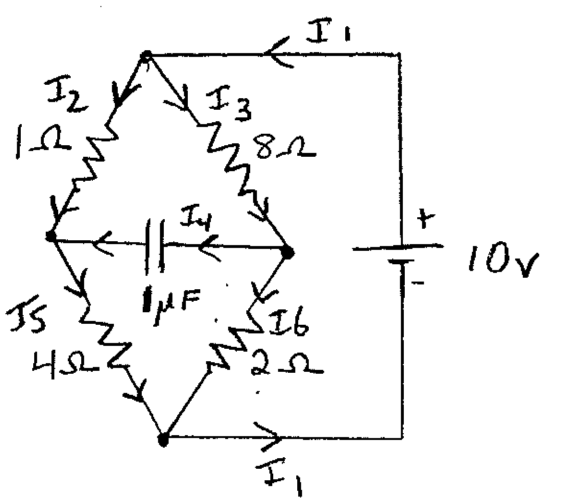
$V_{6\mu F} = 11v$

$q_{6\mu F} = 6.6\times10^{-5}C$

3.

a. From the diagram below, calculate the currents in each branch of the circuit at steady state, also calculate the voltage across the capacitor at steady state.

b. Assuming the capacitor is fully charged and the battery is then disconnected from the circuit, calculate the amount of time it takes the capacitor's charge to decay to 10% of its initial value.



a) $I_1 = 3A$

$I_2 = 2A$

$I_3 = 1A$

$I_4 = 0A$

$I_5 = 2A$

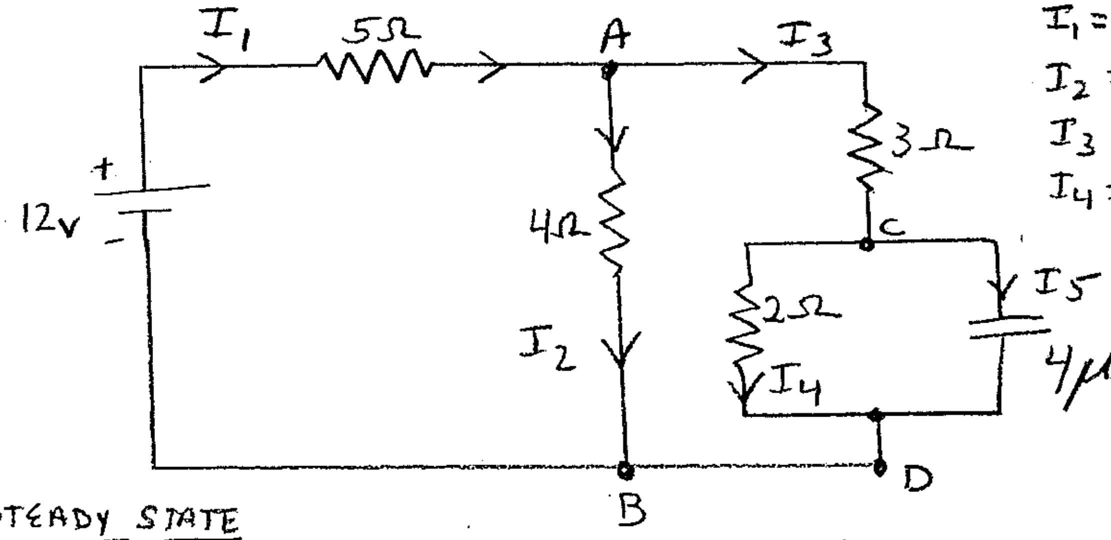
$I_6 = 1A$

$V_{CAP} = 6V$

B) $RC = 3.6\mu s$

∴ TIME = 8.29μs

4. From the diagram below, find the currents at the initial and steady state conditions. Calculate Vab and Vcd in both states also.



Initial

$I_1 = 1.78A$

$I_2 = 0.77A$

$I_3 = 1.02A$

$I_4 = 0$

$I_5 = I_3$

$V_{CD} = 0$

$V_{AB} = 3.08v$

STEADY STATE

$I_1 = 1.66A$

$I_2 = 0.923A$

$I_3 = 0.738A$

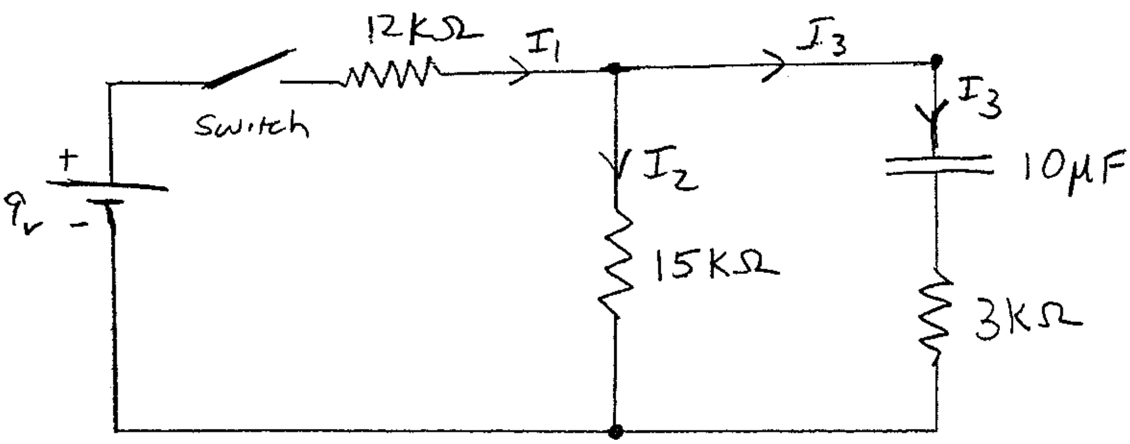
$I_4 = 0.738A$

$I_5 = 0$

$V_{AB} = 3.7v$

$V_{CD} = 1.476v$

5.
a. find the initial and steady state currents through each resistor.
b. calculate the max charge on the capacitor.
c. Find the equation for the current through the 15K ohm resistor after the switch reopens once steady state occurred.



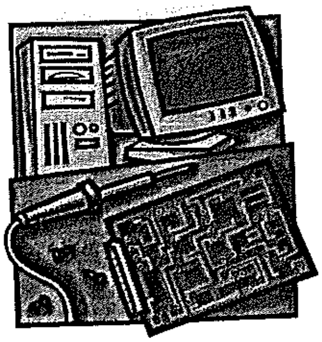
A) $I_1 = I_2 = 0.3\bar{3}mA$, $I_3 = 0$ (STEADY STATE)

$I_1 = .62mA$, $I_2 = 0.103mA$, $I_3 = 0.517mA$ (Initial)

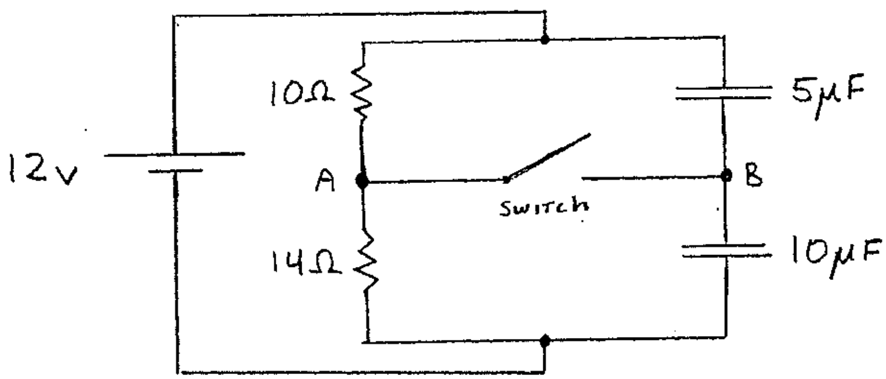
B) 50μc

c) $I = (278\mu A)\, e^{-t/.18sec}$

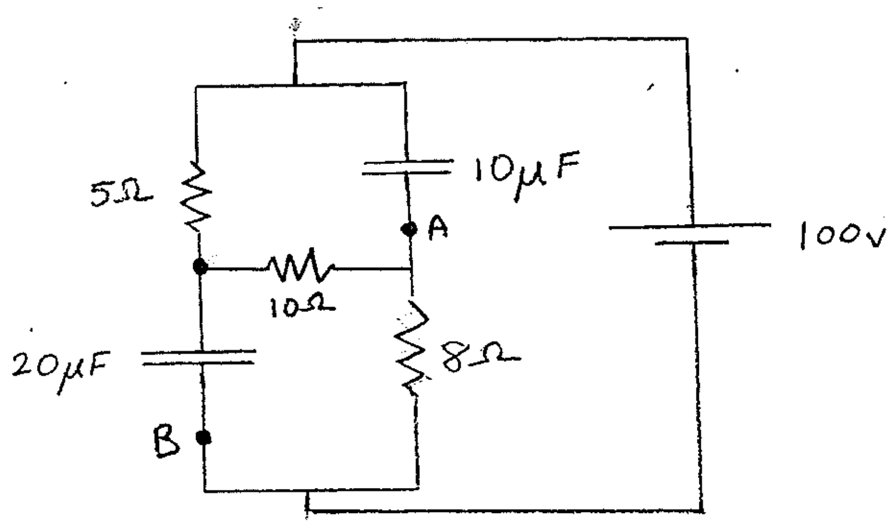
Name_____________________________________ per. ___ date ________
AP Physics B DiBucci
RC Circuits #2



1. In the following circuit calculate
a. Vab at steady state
b. The total amount of charge that flows through the switch if it was closed after steady state was reached.



2. Find Vab at steady state.
Calculate the total energy stored in the capacitors at steady state.



Name______________________________________ **per.**___ **Date** _____

RC Circuit Lab

Directions:

1. Set up the lab as shown by Mr. DiBucci
2. Record the value for your resistor and capacitor here: R=__________
   C=____________
3. Determine your RC time constant : ________
4. Make a diagram of your Charging RC circuit below:
5.

6. Connect the circuit to the battery and record the voltage across the battery every 10 seconds. Record the data for at least four time constants. Collect your data on a separate sheet of paper.

7. Make a graph of your voltage as a function of time .

8. Measure your time constant from the graph and verify that it equal to the time constant you calculated in the first part of the lab.

9. Repeat the lab but now allow the capacitor to discharge through the resistor only.

10. Sketch your circuit here:

11. Collect your data and make your graph on a separate piece of paper.

12. Sketch a graph for the current vs. time for the discharging circuit. Make sure to label your currents at each RC value.