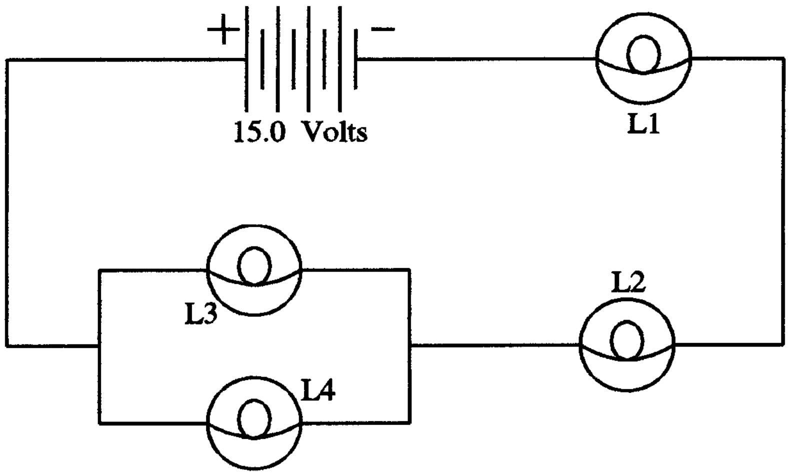
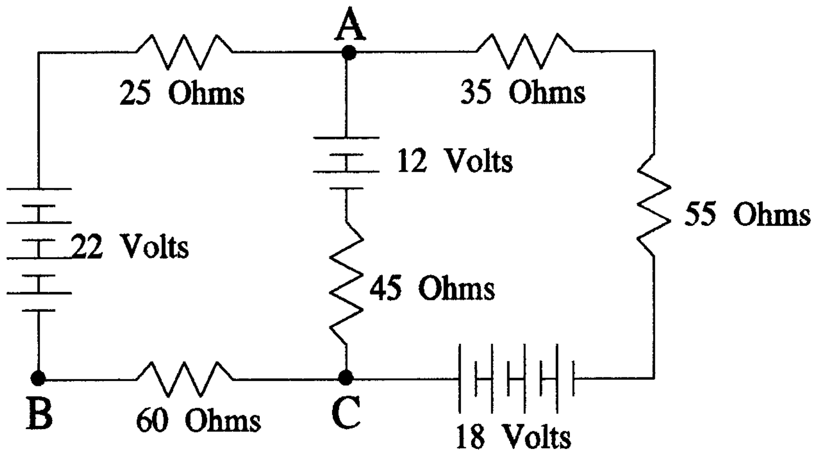
SENIOR PROJECT PHYSICS TEST - 100 PTS - 1991-92
* CHAPTERS 24-25 DC CIRCUITS *

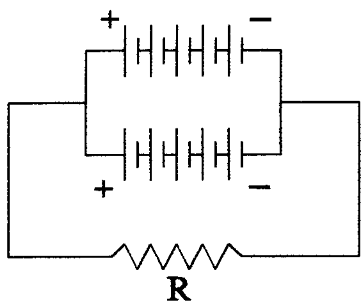
ANSWER FOUR OF THE FOLLOWING QUESTIONS. SHOW ALL WORK CAREFULLY!



1. Each of the following questions refers to the diagram to the right. For each of the following questions you must supply a clear explanation! Each answer is worth 2 points, the explanation is worth 3 points! The explanations are expected to be based on fundamental physical principles , NOT on memorized laws!
   A. How will the currents through Lightbulbs L_1, L_2, L_3 and L_4 compare? Explain! [5 pts]
   B. How will the reading on a voltmeter connected across lightbulb L_4 compare with the reading across lightbulb L_3? Explain! [5 pts]
   C. How will the reading on a voltmeter across lightbulbs L_1, L_2 and L_3 compare? Explain! [5 pts]
   D. Suppose that an ammeter is connected in parallel with lightbulb L_2. Describe **exactly** what will happen in the circuit and why! [5 pts]
   E. Suppose that a voltmeter is connected in series with lightbulb L_3. Describe **exactly** what will happen in the circuit and why! [5 pts]

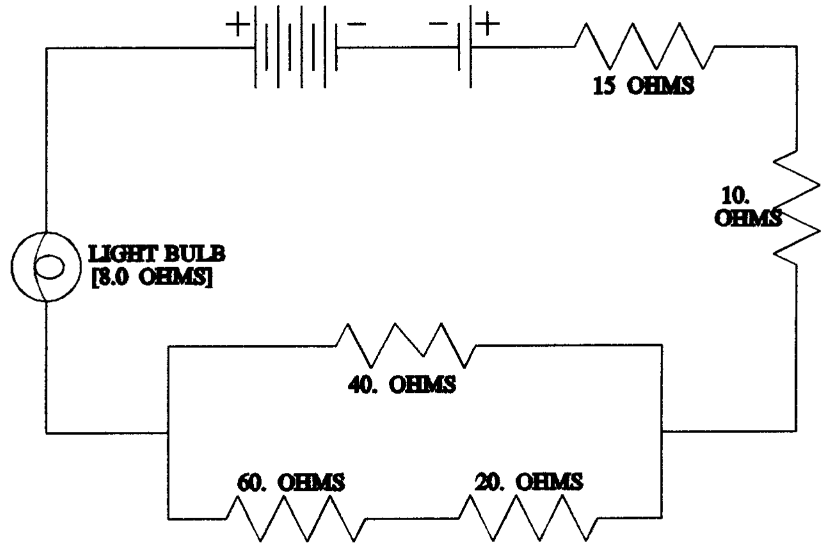


2. Each of the following questions refers to the diagram to the right.
   A. What will be the current flowing through the 35 Ω resistor? [5 pts]
   B. What will be the potential difference across the 25 Ω resistor? [5 pts]
   C. At what rate is energy being dissipated in the 45 Ω resistor? [5 pts]
   D. What will be the potential difference between points A and B? [5 pts]
   E. What will be the potential difference between points A and C? [5 pts]



3. Consider a battery made up of 5 cells connected in series, which is in turn connected in parallel to a second battery, also made up of 5 cells connected in series, as shown in the diagram to the right. Each cell has an internal resistance of .20 Ω and an EMF of 1.53 Volts. This battery, in turn, is to be connected to a load resistance R. Assume initially that this load resistance consists of 3.8 meters of gauge 18 (diameter = 1.024 mm) nickel-silver ($\rho = 49 \times 10^{-8}$ Ω meters) wire.
   A. What will be the resistance of this load? [5 pts]
   B. What will be the magnitude of the current flowing through **each** cell of the battery? [5 pts]
   C. What will be the reading on a voltmeter connected across the battery? [5 pts]
   D. With what efficiency is power being delivered to this load? [5 pts]
   E. Suppose that this load is replaced with another load such that the power delivery in this circuit is maximized. At what rate will energy then be dissipated in this new load? [5 pts]

4. Each of the following questions refers to the diagram to the right. Each cell cell has an EMF of 1.35 Volts and an internal resistance of .35 Ω.



A. What will be the total resistance of this circuit? [5 pts]

B. What will be the current flowing through the 10 Ω resistor? [5 pts]

C. What will be the reading on a voltmeter connected across the 20 Ω resistor? [5 pts]

D. Suppose that the light bulb is immersed in a styrofoam cup filled with 65 milliliters of room temperature [25.0°C] water. What will be the temperature of this water at the end of 15.0 minutes? [Assume that there is no significant loss of heat to the environment!] [5 pts]

E. Suppose that the 60 Ω resistor is replaced by voltmeter [which has a resistance of 100,000 Ω]. Describe **EXACTLY** what will happen to the circuit and calculate the total power being dissipated by the circuit. [5 pts]

5. Answer **THREE** of the following questions as clearly and concisely as possible. [It is intended that no answer to this portion should exceed 1/2 page in length!]

A. What is the internal resistance of a battery, how can it be measured and how is the magnitude of this resistance determined by the internal characteristics of the battery? [10 pts]

B. Explain the differences between voltmeters and ammeters, how they are designed, how they are used and how their characteristics might cause the meters to give incorrect readings. [10 pts]

C. Discuss the characteristics which determine the resistance of a wire, how these characteristics affect the resistance and why? [10 pts]

D. Discuss the theoretical operation of a semi-conductor junction and how it can be used to produce a junction diode. [10 pts]

1. A. $I_1 = I_2 = I_3 + I_4$ [MASS CONSERVATION]

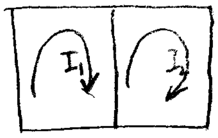
B. $V_4 = V_3$ [ΔV IS FUNCTION OF POSITION]

C. $V_1 + V_2 + V_3 = 15$ [ENERGY CONSERVATION]

D. L_2 WILL GO OUT, $L_1, L_3 + L_4$ WILL GET BRIGHTER. [$\Sigma V = \Sigma EMF$]

E. L_3 WILL GO OUT, L_4 WILL GET BRIGHTER, $L_1 + L_2$ DIMMER

2.



$22 - 12 = 85 I_1 + 45(I_1 - I_2)$ $18 + 12 = 90 I_2 + 45(I_2 - I_1)$

$10 = 130 I_1 - 45 I_2$ $30 = -45 I_1 + 135 I_2$

$130 I_1 = 10 + 45 I_2$ $30 = -45\left[\frac{10 + 45 I_2}{130}\right] + 135 I_2$

$I_1 = \frac{10 + 45 I_2}{130}$ $30 = -3.46 - 15.58 I_2 + 135 I_2$

$= \frac{10 + 45(.28)}{130}$ $33.46 = 119.42 I_2$

$I_1 = .174$ Amps ✓ $I_2 = .280$ Amps ✓

A. $I_{35} = I_2 = \boxed{.280\ A}$ ⓐ 5

B. $V_{25} = I_{25} R_{25} = I_1 (25)$
$= .174(25) = \boxed{4.35 V}$ ⓑ 5

C. $P = I^2 R$
$= (I_1 - I_2)^2 R$
$= (.174 - .280)^2 (45)$
$= .506\ W = \boxed{.51\ \text{WATTS}}$ ⓒ 5

D. $V_{A,B} = 22 - 25(.174) = \boxed{17.65\ \text{VOLTS}}$ ⓓ 5

E. $V_{A,C} = 22 - 85(.174) = \boxed{7.21\ \text{VOLTS}}$ ✓ ⓔ 5

3. $r = .20\ \Omega/\text{cell}$

$\frac{1}{r} = \frac{1}{.2 \times 5} + \frac{1}{.2 \times 5}$

$\frac{1}{r} = 1 + 1 = 2$

$r = .5\ \Omega$

A. $R_{WIRE} = \rho \frac{l}{A} = \frac{49 \times 10^{-8}\ \Omega m\ (3.8 m)}{\pi (.512 \times 10^{-3})^2 m^2} = \boxed{2.26\ \Omega}$ ⓐ 5

B. $\Sigma E = IR = 5(1.53) = I(.5 + 2.26)$
$7.65 = I(2.76)$
$I = \frac{7.65}{2.76} = 2.77$ Amps $\div 2 = \boxed{1.39\ \text{Amps}}$ ⓑ 5

C. $V = IR = -2.77(.5) + 7.65 = \boxed{6.27\ \text{VOLTS}}$ ⓒ 5

D. $EFF = \frac{2.26}{2.26 + .5} = .819 = \boxed{82\%}$ ⓓ 5

E. $\Sigma EMF = [I\ \Sigma R]$
$7.65 = I(1)$
$I = 7.65$ AMPS

$P = I^2 R = 7.65^2 (.5) = \boxed{29.3\ \text{WATTS}}$ ⓔ 5

4. A. $R = 5(.35) = 1.75\ \Omega$ $60 + 20 = 80$, $\frac{1}{80} + \frac{1}{40} = \frac{1}{R_1}$, $R_1 = 26.7 + 10 + 8 + 15 \longrightarrow \boxed{59.7\ \Omega = R_t}$ ⓐ 5

B. $I_t = \frac{V_t}{R_t} = \frac{3(1.35)}{61.5} = \boxed{.066\ \text{Amps}}$ ⓑ 5

C. $I_{20} = \frac{1}{3} I_t = \frac{.066}{3} = .022$ Amps, $V_{20} = I_{20} R_{20} = .022(20) = \boxed{.44\ \text{VOLTS}}$ ⓒ 5

D. $W = Pt = I^2 R t = .066^2 (8)(15 \times 60) = \frac{31.4\ J}{4.19\ J/cal} = 7.49\ cal = mc\Delta t = 65(1)(\Delta t)$
$\Delta t = .12° + 25°C = \boxed{25.12°C}$

E. $\frac{1}{40} + \frac{1}{100{,}020} = \frac{1}{R_1}$, $R_1 = 39.98 \doteq 40\ \Omega + 10 + 15 + 8 + 1.75 = 74.7\ \Omega$

$I = \frac{V}{R} = \frac{3(1.35)}{74.7} = .054 A$ $P = I^2 R = .054^2 (74.7) = \boxed{.22\ \text{WATTS}}$ ⓔ 5