EAS 199A **Homework 2** **Due 10,11 October 2011**

For each of these problems use the *Direct Solution Format* which is described in a document on the web site for homework problems. Problems number 1 and 3 should use the Direct Solution Format. Problems 2, 4 and 5 should use the Engineering Solution Format. Note that the description for problems 4 and 5 is long, but the solution need not take up a lot of space. In fact, for problem 4, the solution should easily fit on a one page, except for the screen shot.

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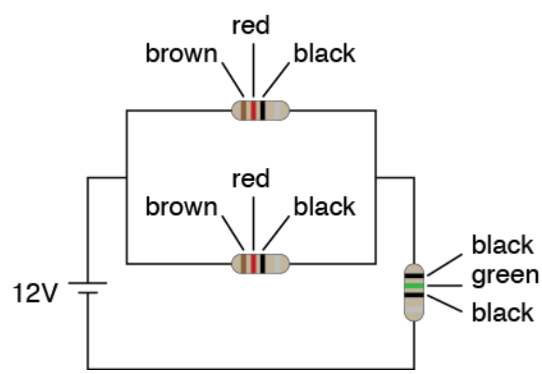
1. Your kit comes with red and yellow LEDs. Build a circuit and write a program that causes the LEDs to be turned on and off in the following pattern:
   (a) At t = 0, both LEDs are turned on.
   (b) At t = 0.5 seconds, the red LED is turned off while the yellow LED remains on.
   (c) At t = 0.75 seconds, the red LED is turned on and the yellow LED is turned off.
   (d) At t = 1 second, the red LED is turned off
   (e) At t = 1.5 seconds, the process repeats starting with step (a).

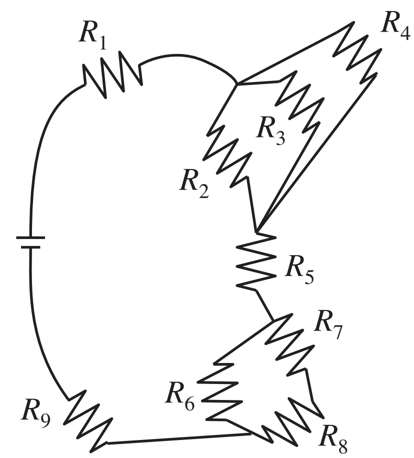
   Print out the program listing and have your Arduino running this program at the start of class on the due date. Keep your homework at your desk and open to your program listing. The instructor will check the function of your blinking LED program and circuit, make a note on your paper, and collect your homework at that point.

2. To the right is a circuit with a 12 volt power source and three resistors.
   (a) Determine the resistance of each resistor based on the color codes.
   (b) Using pencil and paper, obtain the formulas necessary to compute the equivalent resistance of the circuit, the current through the black-green-black resistor, and the power dissipated by the black-green-black resistor.

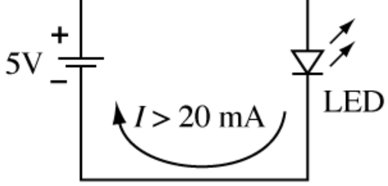


   (c) Evaluate the formulas for the equivalent resistance of the circuit. Answer = 11Ω
   (d) Evaluate the formula for the current flowing through the black-green-black resistor. What is the current?
   (e) Evaluate the formula for the power dissipated by the black-green-black resistor. What is the power?

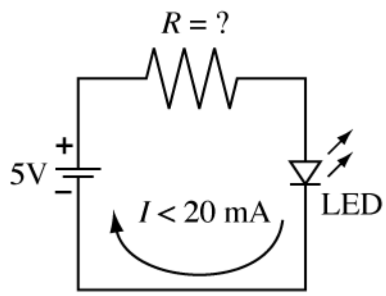
3. Consider the circuit shown to the right.
   (a) Redraw the circuit so that the resistors are oriented parallel to either the horizontal or vertical axes.
   (b) Obtain the equivalent resistance of the circuit if all the resistors are 330Ω.
   (c) Build the circuit on your breadboard and measure the overall resistance. What value do you obtain?



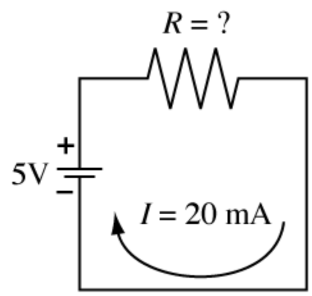
4. An LED has a current limit of 20 mA. Connecting the LED to a 5V supply, as shown in the leftmost diagram, will cause more than 20 mA to flow through the LED, and it will burn out. One solution to this problem is to put a current-limiting resistor in the circuit as shown in the center diagram. Since an LED is a semiconductor, its resistance varies with the applied voltage. Therefore, it is not straightforward to calculate the total resistance of the circuit in the center diagram.



Burn out the LED



LED circuit with current-limiting resistor.



Use this circuit to choose the size of the current-limiting resistor.

   a. Use the diagram at the far right to find the value of the resistance, R, that will limit the current to 20 mA. Show your work. Note that there are on-line calculators for sizing the resistance of an LED. Your solution must show your hand calculations and not rely on an on-line calculator.
   b. If a resistor with the exact resistance computed in part (a) is used in the center circuit, will the current be greater than, less than, or equal to 20 mA? Justify your answer.
   c. Go to the Digikey on-line catalog (see instructions, below) and find the nearest size resistor that will satisfy the design calculation from part (a). Be sure to select a resistor that is in stock, and that does not require a minimum purchase of more than 100 parts. Give a complete specification so that a purchasing agent for your company can order 100 of the resistors. The specification should include the

Digikey part number, the catalog page number, the price, and a URL for the web for the part. Include a screen shot of the part specification.

Instructions for finding a resistor in the on-line Digikey catalog

1. Open www.digikey.com.
2. Enter "resistor" in the Part Search box at the top of the page.
3. Scroll down and click Through Hole Resistors under the Resistors heading
4. Use the filter tool to limit the options. Select these options:
   - select your computed resistance (or something close),
   - 1/4 W power limit,
   - carbon film style resistor.
5. Click the Apply Filters button. If you get a "No records match your search criteria" message, change the value of the resistance while keeping the other constraints.

5. The analysis in the preceding problem is conservative because it neglects the voltage drop across the LED. The manufacturer of the LED publishes a datasheet that provides important information that can be used in designing a circuit that uses the LED. The full datasheet for the LED in the Sparkfun Inventer's kit can be downloaded as a PDF document:

   `http://www.sparkfun.com/datasheets/Components/LED/COM-00533-YSL-R531R3D-D2.pdf.`

   The link to the PDF is on the catalog page for the LED,

   `http://www.sparkfun.com/commerce/product_info.php?products_id=533.`

   Excerpts from the data sheet are shown at the top of the following page. The key data for our current analysis are

   Forward current: $I_F = 20$ mA

   Suggested forward current: $I_{SU} = 16 – 18$ mA "Suggested Using Current"

   Forward voltage: $V_F = 1.8 – 2.2$ V

   The forward current is the maximum current that the circuit should be designed supply to the LED. The Suggested Using Current is the value of the forward current recommended for regular use. The forward voltage is the voltage drop across the LED when the forward current is obtained. In other words, if the voltage across the LED is limited to the forward voltage, the desired forward current will flow through the LED. The reverse voltage is the maximum reverse voltage that can be applied to the LED before current flows in the reverse direction. In general, exceeding either the forward voltage or the reverse voltage will damage the LED.

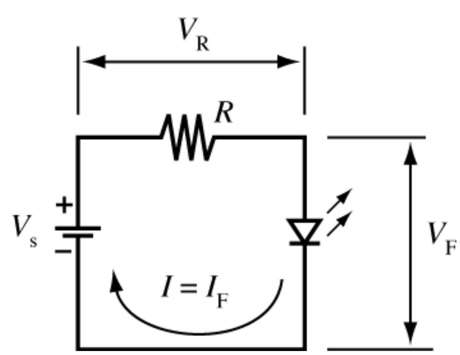
Absolute Maximum Ratings: (Ta=25℃) .

ITEMS	Symbol	Absolute Maximum Rating	Unit
Forward Current	I_F	20	mA
Peak Forward Current	I_{FP}	30	mA
Suggestion Using Current	I_{su}	16-18	mA
Reverse Voltage (V_R=5V)	I_R	10	uA
Power Dissipation	P_D	105	mW
Operation Temperature	T_{OPR}	-40 ~ 85	℃
Storage Temperature	T_{STG}	-40 ~ 100	℃
Lead Soldering Temperature	T_{SOL}	Max. 260℃ for 3 Sec. Max. (3mm from the base of the expoxy bulb)	

Absolute Maximum Ratings: (Ta=25℃)

ITEMS	Symbol	Test condition	Min.	Typ.	Max.	Unit
Forward Voltage	V_F	I_F=20mA	1.8	---	2.2	V
Wavelenength (nm) or TC(k)	Δ λ	I_F=20mA	620	---	625	nm
*Luminous intensity	I_V	I_F=20mA	150	---	200	mcd
50% Viewing Angle	2 θ 1/2	I_F=20mA	40	---	60	deg

Given the information from the datasheet, it is possible to make a more precise specification of the current-limiting resistor. The following schematic shows the circuit with the forward voltage and forward current labeled.



a. Use Kirchoff's voltage law and Ohm's law to find an equation for the current-limiting resistor as a function of the forward current I_F, forward voltage V_F, and the supply voltage, V_s. Your formula should be of the form $R = f(V_F, V_s, I_F)$. Do not use any numerical values in this formula.

b. For V_s = 5V and the specifications in the datasheet, what value of R do you recommend? The value should be equal to the resistance of a part from the Digikey catalog. In other words, don't recommend a part that you can't buy. Show your calculations to obtain R. List the part number, cost per 100 resistors (or other quantity) and include a screen shot of the part page.

c. Use your formula from part (a) to make a table of recommended R values for $V_s = 2, 3, 4, 5, 9, 12$ V. Use the following format for the table. Show your calculations for $V_s = 9$ V. The "Exact R" value is the resistance you compute with your formula. The "Recommended R" is the resistance of a part that you can buy.

V_s (V)	Exact R (Ω)	Recommended R (Ω)
2		
3		
4		
5		
9		
12		