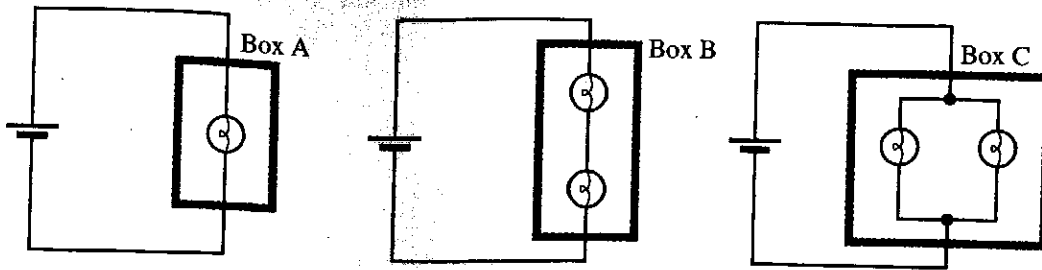


A MODEL FOR CIRCUITS

PART 1: CURRENT AND RESISTANCE

1. In tutorial, you compared the relative brightness of the bulbs in the three circuits shown. In the diagrams, boxes have been drawn around the networks of bulbs in each circuit.



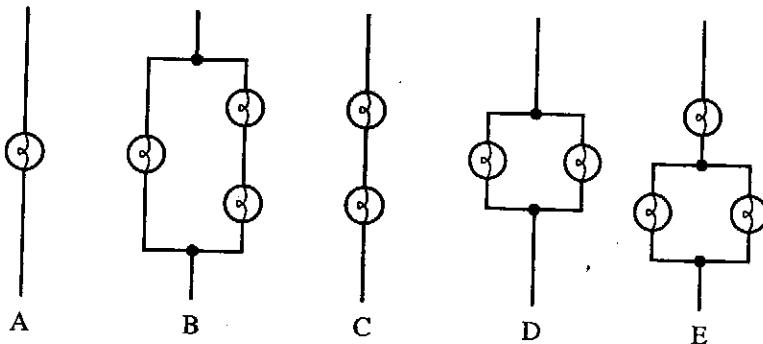
On the basis of your observations and the rule you developed in tutorial relating current through the battery to total resistance, rank the networks (boxes) A-C according to their equivalent resistance. Explain your reasoning on the basis of the model. (Do not use math.)

$$R_B > R_A > R_C$$

According to our model, charges must travel through twice as many obstacles for Box B so $R_B > R_A$. Comparing Box C and A, charges have more ways to travel for box C, so $R_A > R_C$.

Math: $R_{eq} = 2R$ for B, and $\frac{1}{R_{eq}} = \frac{1}{R} + \frac{1}{R} = \frac{2}{R} \Rightarrow R_{eq} = \frac{R}{2}$ for C

2. Use the model for electric current to rank the networks shown below in order according to resistance. Explain your reasoning.



$R_C > R_A > R_D$ as above, what about B, E?
 $R_E > R_A$ since it's adding resistance in series
 But $R_C > R_E$ since resistance of parallel part of E is less than R
 so $R_C > R_E > R_A > R_D$. What about B? $R_B < R_A$, since R_{eq} of parallel network is less than resistance of any 'arm'. But
 $R_B > R_D$ because one branch has greater resistance.

$$R_C > R_E > R_A > R_B > R_D$$

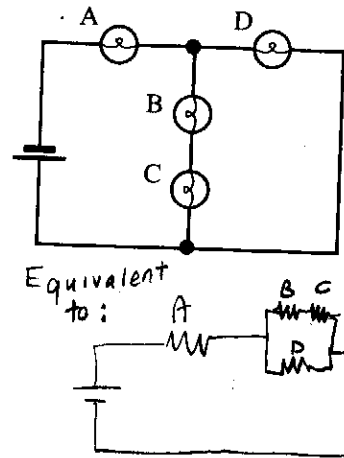
3. The circuit shown has four identical light bulbs and an ideal battery.

a. Rank the brightness of the bulbs. Explain your reasoning.

Brightness $\propto I$ $I = V/R$
 R_B & R_C are in series. $I_B = I_C$
 This branch is in || with R_D . More current through the lower resistance branch, R_D
 so $I_D > I_{B,C}$

$I_A = I_D + I_{B,C}$ so $I_A > I_D > I_{B,C}$

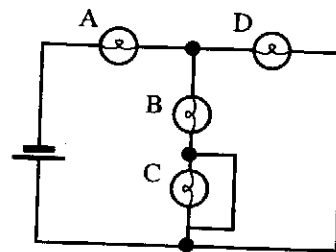
Bulb brightness is in the same order



b. A wire is now added to the circuit as shown.

i. Does the brightness of bulb C increase, decrease, or remain the same? Explain your reasoning.

Decreases: in fact, bulb goes out! - that's a 'short circuit'. All the current goes via zero resistance path.



ii. Does the brightness of bulb A increase, decrease, or remain the same? Explain.

The total resistance of the network decreases

$I_A = I_{tot}$, I_{tot} increases

so I_A increases

and bulb gets brighter

meth: Before,
 $R_{equiv} = R_A + R_{DBC}$
 $R_{DBC} = \frac{R_D R_{BC}}{R_D + R_{BC}}$, $R_{BC} = 2R$
 $= \frac{R(2R)}{R+2R} = \frac{2}{3}R$
 $R_{equiv} = \frac{5}{3}R$
 After: $R_{DBC} = \frac{R_D R_B}{R_D + R_B} = \frac{R}{2}$
 $R_{equiv} = \frac{3}{2}R$; less than before

iii. Does the current through the battery increase, decrease, or remain the same? Explain.

Total current increases because V is constant and total resistance decreases

$I_{tot} = \frac{V}{R_{equiv}}$

A MODEL FOR CIRCUITS

PART 1: CURRENT AND RESISTANCE

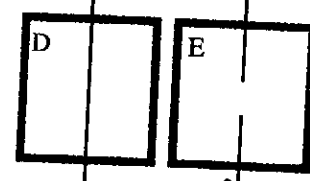
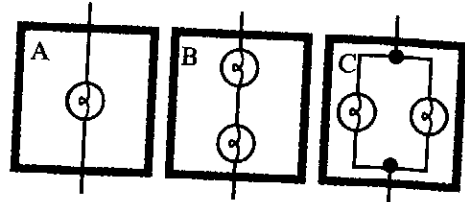
Name _____

EM
HW-93

4. Consider the five networks shown at right.

a. Rank the networks according to their equivalent resistance. (Hint: Imagine placing each network in series with an indicator bulb and a battery.)

$$R_E > R_B > R_A > R_C > R_D$$



zero resistance
infinite resistance (open circuit)

b. How does adding a single bulb to a circuit in *series* with another bulb or network affect the resistance of the circuit?

Increases R_{equiv}

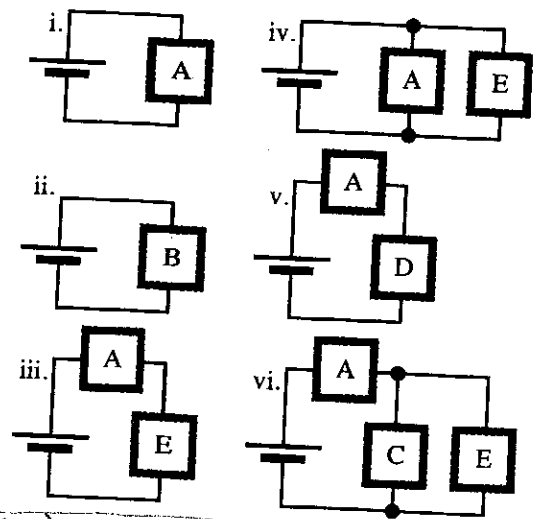
c. How does adding a single bulb to a circuit in *parallel* with another bulb or network affect the resistance of the circuit?

Decreases R_{equiv}

d. The networks A-E above are connected, in turn, to identical batteries as shown. Use the model we have developed to:

• rank the circuits according to equivalent resistance. Explain.

$R_{ii} > R_i$ because $R_B > R_A$
 R_E has infinite resistance,
 $\Rightarrow R_{iii} = \infty$. Also E has no effect
 in parallel, so $R_{iv} = R_i$
 R_D has zero resistance, so $R_v = R_i$
 In vi, E has no effect; $R_{vi} > R_i$, but
 since $R_C < R_A$, $R_{vi} < R_{ii}$ so:



$$R_{iii} > R_{ii} > R_{vi} > R_i = R_v = R_{iv}$$

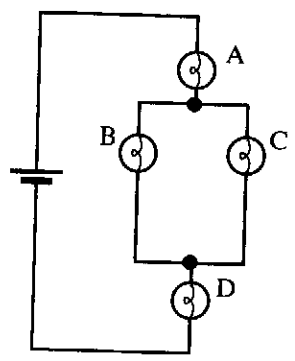
• rank the circuits according to the current through the battery. Explain.

$$I \propto \frac{1}{R}$$

so

$$I_{iii} < I_{ii} < I_{vi} < I_i = I_v = I_{iv}$$

5. The circuit below shows four identical bulbs connected to an ideal battery.



a. Rank the bulbs in order from brightest to dimmest. If two bulbs have the same brightness, indicate that explicitly.

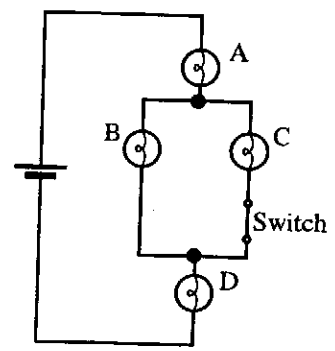
Explain how you determined the ranking of the bulbs.

$$I_A = I_D$$

$$I_B = I_C < I_{A,D}$$

$$\text{so } I_A = I_D > I_B = I_C$$

b. Suppose that a switch has been added to the circuit as shown. The switch is initially closed.



When the switch is opened, will the current through bulb A increase, decrease, or remain the same? Explain how you determined your answer.

When the switch is opened, the branch with R_C is 'open circuit' and no current flows

⇒ resistance of B & C || part increases
 (fewer ways for current to flow)
 ⇒ total network resistance increases
 ⇒ current through A decreases

Math: Before, $R_{equiv} = R_A + R_D + \frac{R_B R_C}{R_B + R_C} = 2R + \frac{R^2}{2R} = \frac{5}{2}R$

After switch opened, $R_{equiv} = R_A + R_B + R_C = 3R$, greater.

WUNZK

- model of current $I = n v_d A q$

- Current density $J = \frac{I}{A}$

- $V = IR$ Ohm's Law (comes from this model)

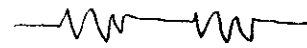
- $R = \rho \frac{l}{A}$
↑ resistance
resistivity property of material

- Series

$$R_{eq} = R_1 + R_2$$
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

Parallel

also comes from model

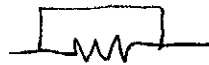


total R increases



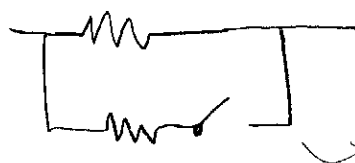
total R decreases

- short circuit



$R_{eq} = 0$

open circuit



$R = \infty$