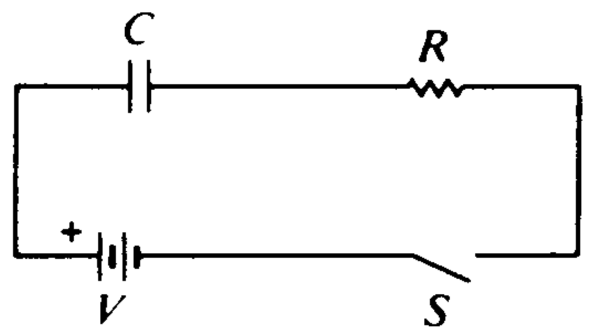
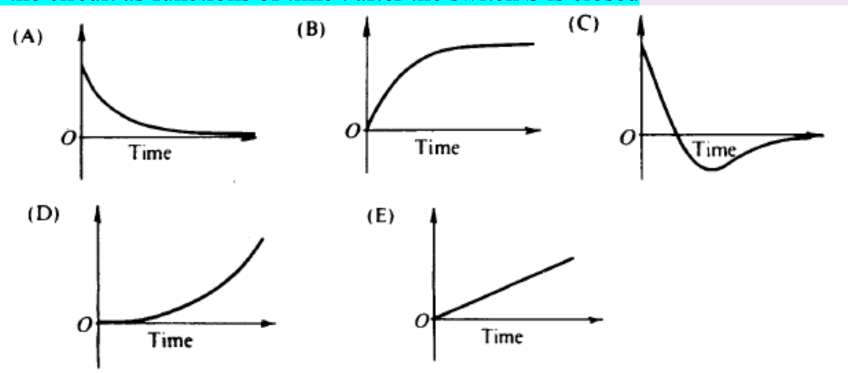
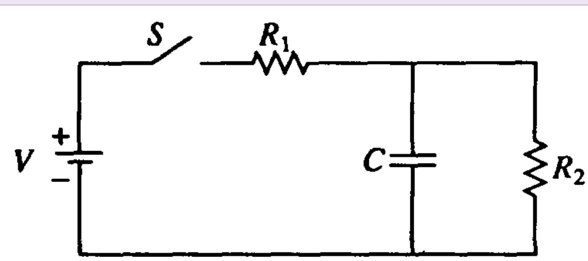
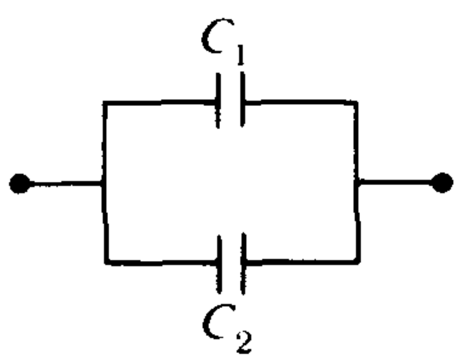
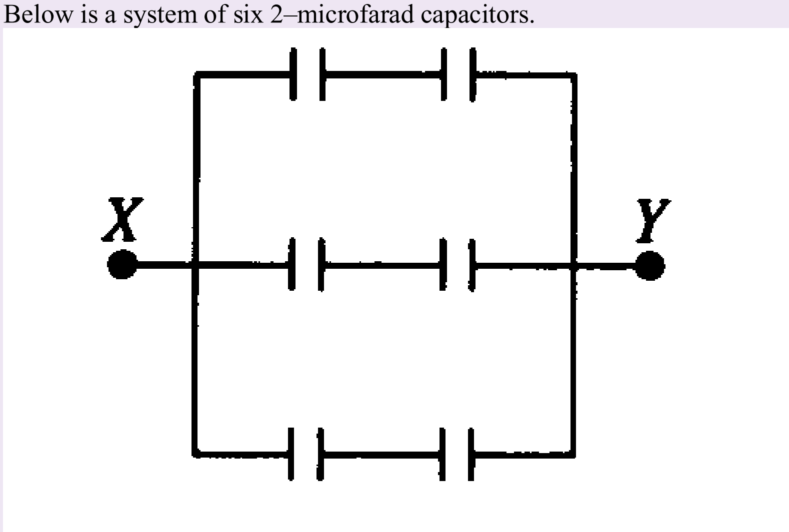
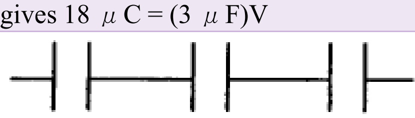
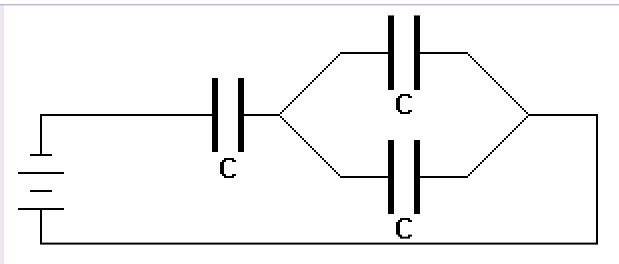
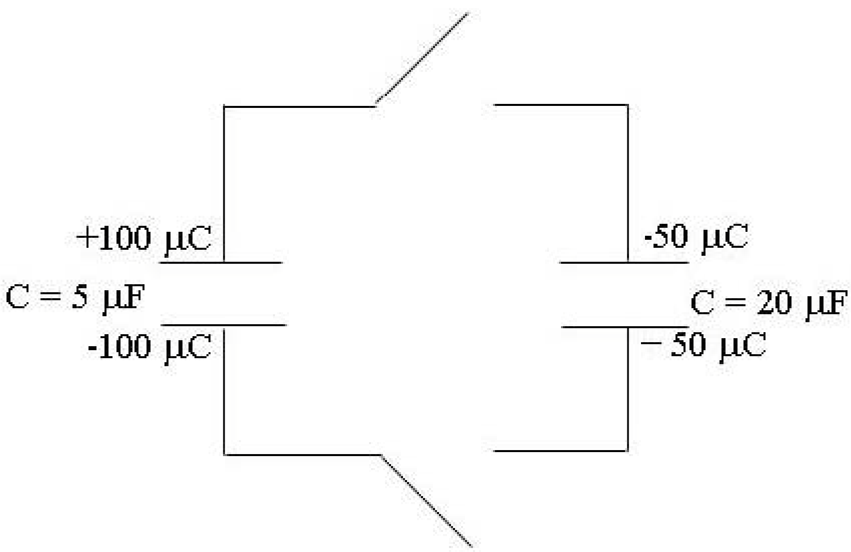
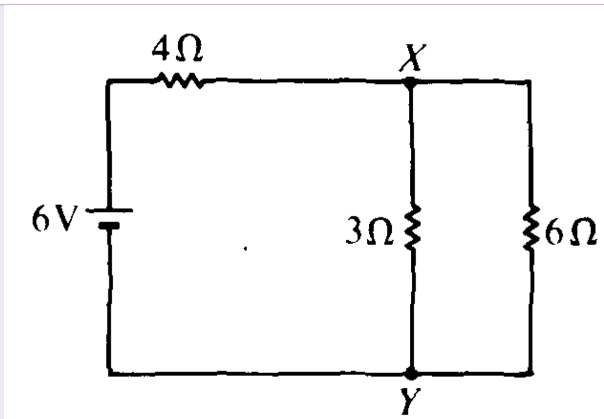
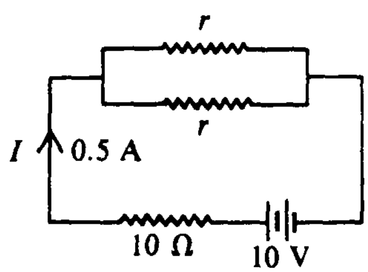
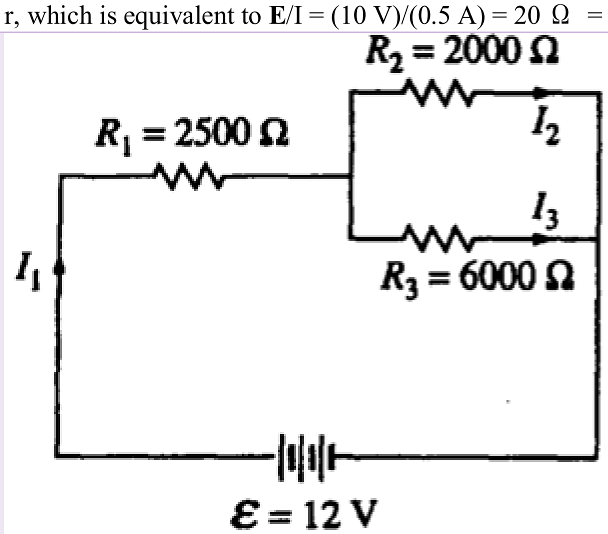
Archive: Circuits

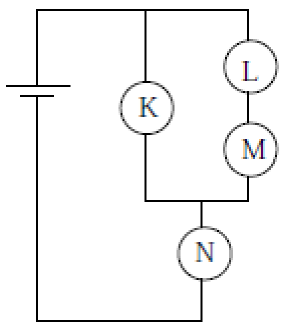
#	Question	Subtopic	Level
42-43	 Assume the capacitor C is initially uncharged. The following graphs may represent different quantities related to the circuit as functions of time t after the switch S is closed  42. Which graph best represents the voltage versus time across the resistor R? **(A)A** (B)B (C)C (D)D (E) E *When the switch is closed, the circuit behaves as if the capacitor were just a wire and all the* *potential of the battery is across the resistor. As the capacitor charges, the voltage changes over* *to the capacitor over time, eventually making the current (and the potential difference across the* *resistor) zero and the potential difference across the capacitor equal to the emf of the battery.* 43. Which graph best represents the current versus time in the circuit? **(A)A** (B)B (C)C (D)D (E) E *See above* 44. Which graph best represents the voltage across the capacitor versus time? (A)A **(B)B** (C)C (D)D (E) E *See above*		
55-56	 In the circuit shown above, the battery supplies a constant voltage V when the switch S is closed. The value of the capacitance is C, and the value of the resistances are R_1 and R_2.		

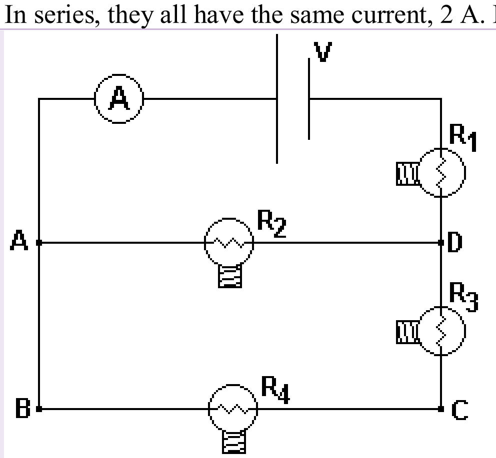
	Immediately after the switch is closed, the current supplied by the battery is (A) $V/(R_1 + R_2)$ (B) V/R_1 (C) V/R_2 (D) $V(R_1 + R_2)/R_1R_2$ (E) zero *When the switch is closed, the circuit behaves as if the capacitor were just a wire, shorting out* *the resistor on the right.* A long time after the switch has been closed, the current supplied by the battery is **(A) $V/(R_1 + R_2)$** (B) V/R_1 (C) V/R_2 (D) $V(R_1 + R_2)/R_1R_2$ (E) zero When the capacitor is fully charged, the branch with the capacitor is "closed" to current, effectively removing it from the circuit for current analysis.		
40	The emf of a battery is 12 volts. When the battery delivers a current of 0.5 ampere to a load, the potential difference between the terminals of the battery is 10 volts. The internal resistance of the battery is (A) 1 Ω (B) 2 Ω **(C) 4 Ω** (D) 20 Ω (E) 24 Ω $V_T = \mathbf{E} - Ir$		1
84	When any four resistors are connected in parallel, the _______ each resistor is the same. (A) charge on (B) current through (C) power from (D) resistance of **(E) voltage across** by definition of a parallel circuit	Basics	1
39	When two identical parallel–plate capacitors are connected in series, which of the following is true of the equivalent capacitance? (A) It depends on the charge on each capacitor. (B) It depends on the potential difference across both capacitors. (C) It is larger than the capacitance of each capacitor. **(D) It is smaller than the capacitance of each capacitor.** (E) It is the same as the capacitance of each capacitor *In series, the equivalent capacitance is calculated using reciprocals, like resistors in parallel. This* *results in an equivalent capacitance smaller than the smallest capacitor.*	Capacitance	
5	 Two capacitors are connected in parallel as shown above. A voltage V is applied to the pair. What is the ratio of charge stored on C_1 to the charge stored on C_2, when $C_1 = 1.5C_2$? (A) 4/9 (B) 2/3 (C) 1 **(D) 3/2** (E) 9/4 In parallel $V_1 = V_2$. $Q_1 = C_1V_1$ and $Q_2 = C_2V_2$ so $Q_1/Q_2 = C_1/C_2 = 1.5$	Capacitor Equivalents	
27	The total capacitance of several capacitors in parallel is the sum of the individual capacitances for which of the following reasons? **(A) The charge on each capacitor depends on its capacitance, but the potential difference across each is the** **same.** (B) The charge is the same on each capacitor, but the potential difference across each capacitor depends on its capacitance.	Capacitors	

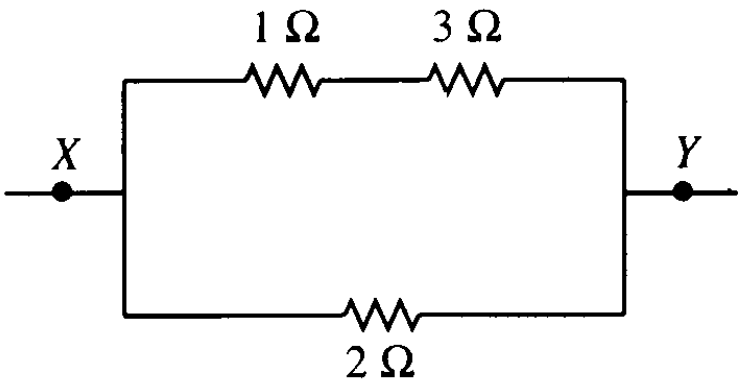
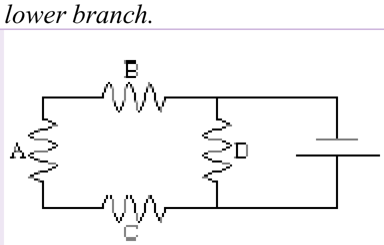
	(C) Equivalent capacitance is always greater than the largest capacitance. (D) Capacitors in a circuit always combine like resistors in series. (E) The parallel combination increases the effective separation of the plates By process of elimination, A is the only possible true statement.		
45-46	Three 6–microfarad capacitors are connected in series with a 6–volt battery. The equivalent capacitance of the set of capacitors is (A) 0.5 μ F **(B) 2 μ F** (C) 3 μ F (D) 9 μ F (E) 18 μ F In series $\frac{1}{C_T} = \sum \frac{1}{C}$ The energy stored in each capacitor is (A) 4 μ J (B) 6 μ J **(C) 12 μ J** (D) 18 μ J (E) 36 μ J There are several ways to do this problem. We can find the total energy stored and divide it into the three capacitors: $U_C = ½ CV^2 = ½ (2\ \mu F)(6\ V)^2 = 36\ \mu J \div 3 = 12\ \mu J$ each	Capacitors	
50-51	Below is a system of six 2–microfarad capacitors.  The equivalent capacitance of the system of capacitors is (A) 2/3 μ F (B) 4/3 μ F **(C) 3 μ F** (D) 6 μ F (E) 12 μ F Each branch, with two capacitors in series, has an equivalent capacitance of 2 μ F ÷ 2 = 1 μ F. The three branches in parallel have an equivalent capacitance of 1 μ F + 1 μ F + 1 μ F = 3 μ F What potential difference must be applied between points X and Y so that the charge on each plate of each capacitor will have magnitude 6 microcoulombs? (A) 1.5 V (B) 3V **(C) 6 V** (D) 9 V (E) 18 V For each capacitor to have 6 μ C, each *branch* will have 6 μ C since the two capacitors in series in each branch has the same charge. The total charge for the three branches is then 18 μ C. Q = CV gives 18 μ C = (3 μ F)V	Capacitors	
66	 Three 1/2 μ F capacitors are connected in series as shown in the diagram	capacitors	

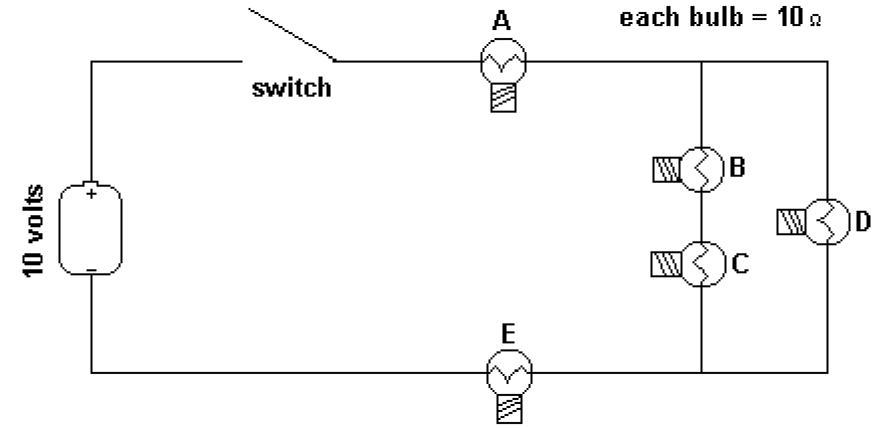
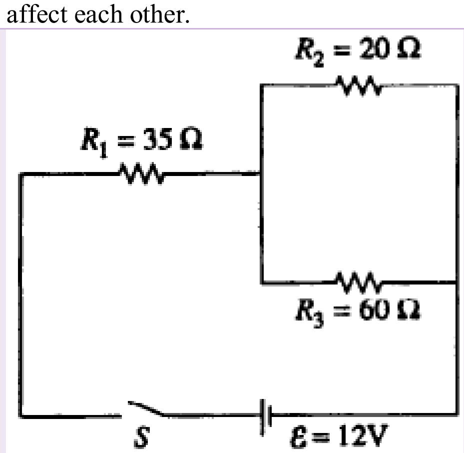
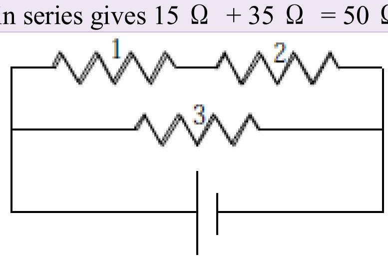
	above. The capacitance of the combination is (A) 0.1 μF (B) 1 μF (C) 2/3 μF (D) ½ μF (E) 1/6 μF In series $\frac{1}{C_T} = \sum \frac{1}{C}$		
98	 Three identical capacitors each with a capacitance of *C* are connected as shown in the following diagram. What would be the total equivalent capacitance of the circuit? (A) 0.33 *C* **(B) 0.67** *C* (C) 1.0 *C* (D) 1.5 *C* (E) 3.0 *C* The capacitance of the two capacitors in parallel is 2C. Combined with a capacitor in series gives $C = \frac{C \times 2C}{C + 2C} = \frac{2}{3}C$	Capacitors	
119	 For the configuration of capacitors shown, both switches are closed simultaneously. After equilibrium is established, what is the charge on the top plate of the 5 μF capacitor? (A) 100 μC (B) 50 μC (C) 30 μC (D) 25 μC **(E) 10 μC** The total charge to be distributed is +100 μC – 50 μC = + 50 μC. In parallel, the capacitors must have the same voltage so the 20 μF capacitor has four times the charge of the 5 μF capacitor. This gives $Q_{20} = 4Q_5$ and $Q_{20} + Q_5 = 4Q_5 + Q_5 = 5Q_5 = 50$ μC, or Q_5 E = 10 μC	Capacitors	

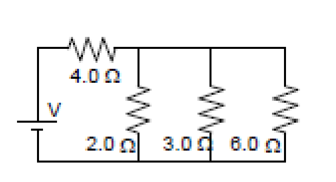
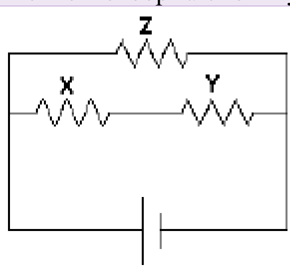
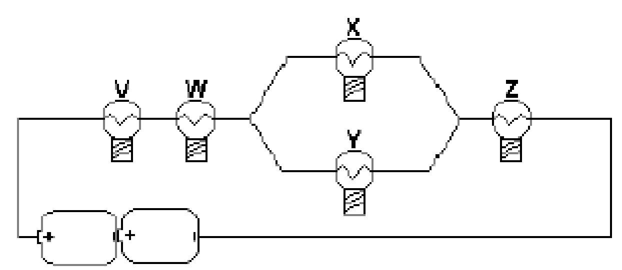
2	 In the circuit shown above, what is the value of the potential difference between points X and Y if the 6–volt battery has no internal resistance? (A) 1 V **(B) 2 V** (C) 3 V (D) 4 V (E) 6V The total resistance of the 3 Ω and 6 Ω in parallel is 2 Ω making the total circuit resistance 6 Ω and the total current **E**/R = 1 A. This 1 A will divide in the ratio of 2:1 through the 3 Ω and 6 Ω respectively so the 3 Ω resistor receives 2/3 A making the potential difference IR = (2/3 A)(3 Ω) = 2 V.	Combination Ohm’s	1
12	 In the circuit shown above, the value of r for which the current I is 0.5 ampere is (A) 0 Ω (B) 1 Ω (C) 5 Ω (D) 10 Ω **(E) 20 Ω** The resistance of the two resistors in parallel is r/2. The total circuit resistance is then 10 Ω + ½ r, which is equivalent to **E**/I = (10 V)/(0.5 A) = 20 Ω = 10 Ω + r/2	Combination	1
30-31	 What is the current I_1? (A) 0.8 mA (B) 1.0 mA (C) 2.0 mA **(D) 3.0 mA** (E) 6.0 mA *Resistance of the 2000 Ω and 6000 Ω in parallel = 1500 Ω, adding the 2500 Ω in*	Equivalent	2

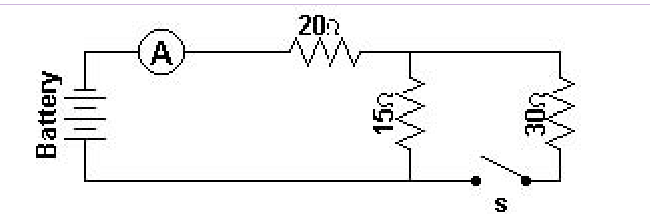
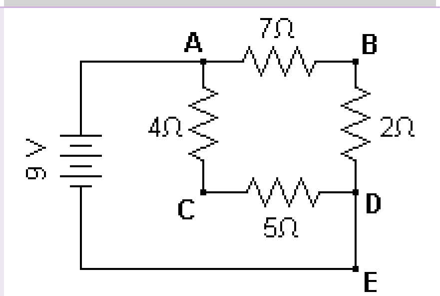
	series gives a *total circuit resistance of 4000 Ω.* $I_{total} = I_1 = \mathbf{E}/R$ *D* total How do the currents I_1, I_2, and I_3 compare? **(A)** $\mathbf{I_1 > I_2 > I_3}$ (B) $I_1 > I_3 > I_2$ (C) $I_2 > I_1 > I_3$ (D) $I_3 > I_1 > I_2$ (E) $I_3 > I_2 > I_1$ *I1 is the main branch current and is the largest. It will split into I2 and I3and since I2 moves* *through the smaller resistor, it will be larger than I3*		
74-77	 Four identical light bulbs K, L, M, and N are connected in the electrical circuit shown above. Rank the current through the bulbs. (A) K > L > M > N (B) L = M > K = N (C) L > M > K > N (D) N > K > L = M (E) N > L = M > K Answer: D N is in the main branch, with the most current. The current then divides into the two branches, with K receiving twice the current as L and M. The L/M branch has twice the resistance of the K branch. L and M in series have the same current. In order of decreasing brightness (starting with the brightest), the bulbs are: (A) K = L > M > N (B) K = L = M > N (C) K > L = M > N (D) N > K > L = M (E) N > K = L = M Answer: D See above. Current is related to brightness ($P = I^2R$) Bulb K burns out. Which of the following statements is true? (A) All the light bulbs go out. (B) Only bulb N goes out. (C) Bulb N becomes brighter. (D) The brightness of bulb N remains the same. (E) Bulb N becomes dimmer but does not go out. Answer: E If K burns out, the circuit becomes a series circuit with the three resistors, N, M and L all	Equivalent Power Brightness	

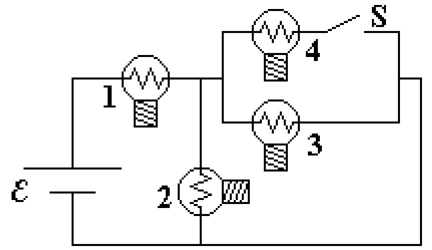
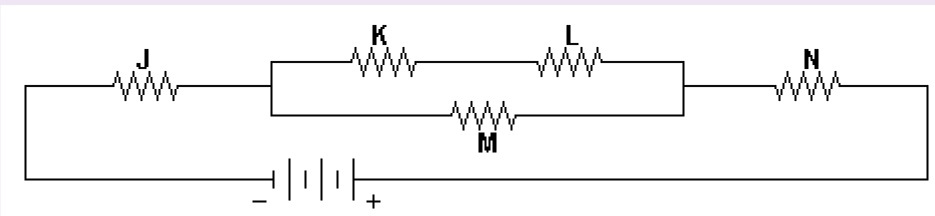
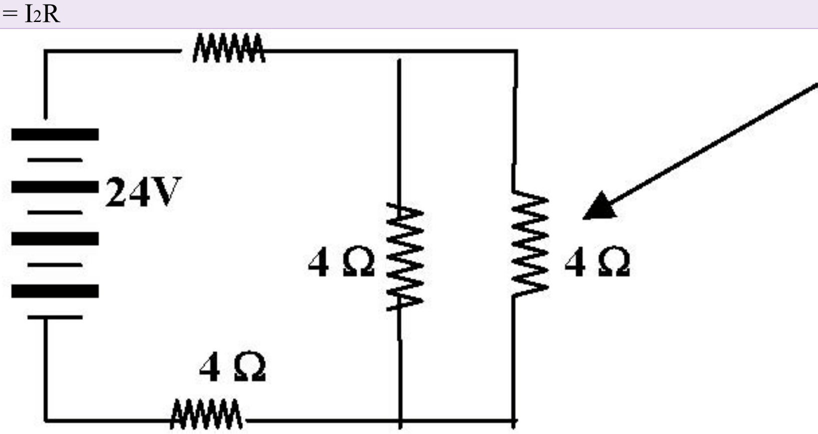
	in series, reducing the current through bulb N. Bulb M burns out. Which of the following statements is true? (A) All the light bulbs go out. (B) Only bulb M goes out. (C) Bulb N goes out but at least one other bulb remains lit. (D) The brightness of bulb N remains the same. (E) Bulb N becomes dimmer but does not go out. Answer: E If M burns out, the circuit becomes a series circuit with the two resistors, N and K in series, with bulb L going out as well since it is in series with bulb M.		
79	When two resistors, having resistance R_1 and R_2, are connected in parallel, the equivalent resistance of the combination is 5 Ω. Which of the following statements about the resistances is correct? (A) Both R_1 and R_2 are greater than 5 Ω. (B) Both R_1 and R_2 are equal to 5 Ω. (C) Both R_1 and R_2 are less than 5 Ω. (D) The sum of R_1 and R_2 is 5 Ω. (E) One of the resistances is greater than 5 Ω, one of the resistances is less than 5 Ω. Answer: A The equivalent resistance in parallel is smaller than the smallest resistance.	Equivalent	
81	Three resistors – R_1, R_2, and R_3 – are connected in series to a battery. Suppose R_1 carries a current of 2.0 A, R_2 has a resistance of 3.0 Ω, and R_3 dissipates 6.0 W of power. What is the voltage across R_3 (A) 1.0 V (B) 2.0 V **(C) 3.0 V** (D) 6.0 V (E) 12 V In series, they all have the same current, 2 A. $P_3 = I_3V_3$	Equivalent Power	
11 3	 The circuit shown has an ideal ammeter with zero resistance and four identical resistance light bulbs which are initially illuminated. A person removes the bulb R_4 from its socket thereby permanently breaking the electrical circuit at that point. Which statement is true of the circuit after removing the bulb? **(A) The voltage from B → C increases.** (B) The power supplied by the battery increases (C) The voltage across R_1 (D) The ammeter reading is unchanged. increases. (E) The bulb R_2 maintains the same brightness. Breaking the circuit in the lower branch lowers the total current in the circuit, decreasing the voltage across R_1. Looking at the upper loop, this means R_2	Equivalent Power	

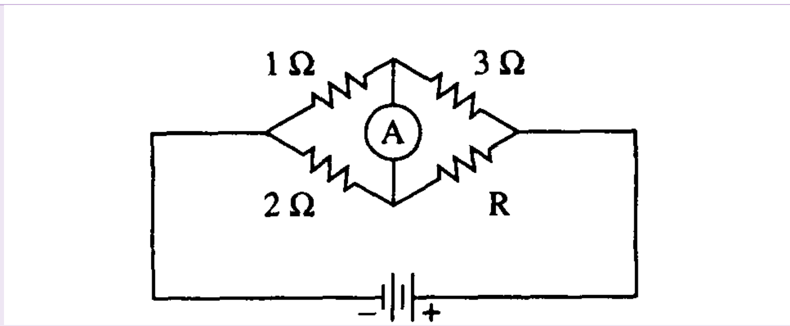
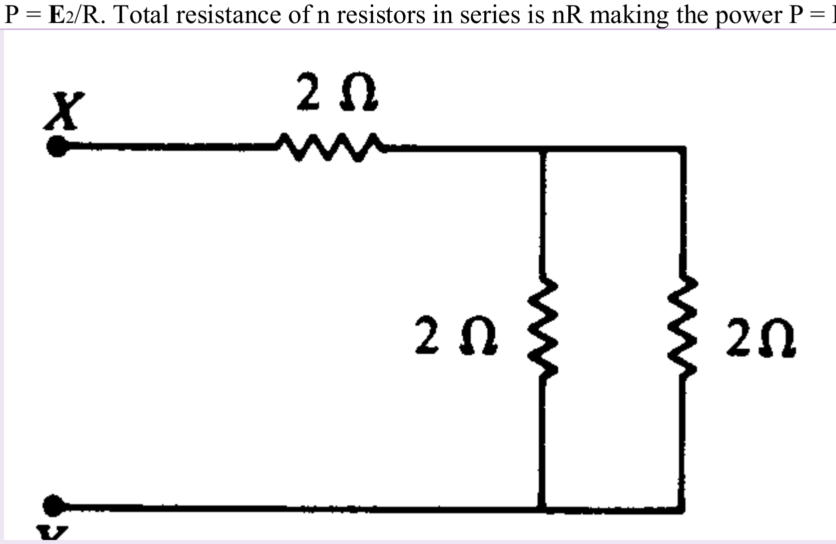
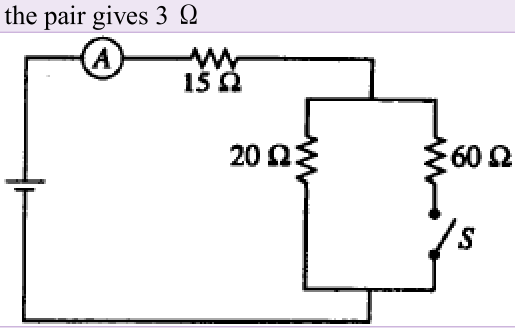
	A now has a larger share of the battery voltage and the voltage across AD is the same as the voltage across BC		
22-23	 The electrical resistance of the part of the circuit shown between point X and point Y is **(A) 4/3 Ω** (B) 2 Ω (C) 2.75 Ω (D) 4 Ω (E) 6 Ω *Resistance of the 1 Ω and 3 Ω in series = 4 Ω. This, in parallel with the 2 Ω resistor gives (2 × 4)* */(2 + 4) = 8/6 Ω. Also notice the equivalent resistance must be less than 2 Ω (the 2 Ω resistor is* *in parallel and the total resistance in parallel is smaller than the smallest resistor) and there is* *only one choice smaller than 2 Ω.* When there is a steady current in the circuit, the amount of charge passing a point per unit of time is (A) the same everywhere in the circuit (D) greater at point X than at point Y (B) greater in the 1 Ω resistor than in the 2 Ω resistor (E) greater in the 1 Ω resistor than in the 3 Ω resistor **(C) greater in the 2 Ω** resistor than in the 3 Ω resistor *The upper branch, with twice the resistance of the lower branch, will have ½ the current of the* *lower branch.*	Equivalent	1
95	 If all of the resistors in the above simple circuit have the same resistance, which would dissipate the greatest power? (A) resistor A (B) resistor B (C) resistor C **(D) resistor D** (E) they would all dissipate the same power Resistor D is in a branch by itself while resistors A, B and C are in series, drawing less current than resistor D.	Equivalent Power	1
100-101	Five identical light bulbs, each with a resistance of 10 ohms, are connected in a simple electrical circuit with a switch and a 10 volt battery as shown in the diagram below.	Equivalent	1

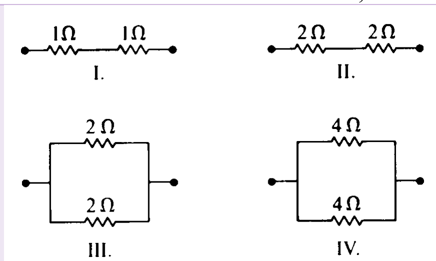
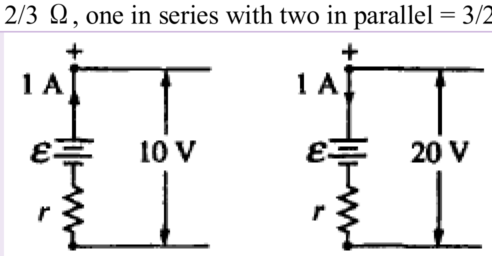
	 The steady current in the above circuit would be closest to which of the following values? (A) 0.2 amp **(B) 0.37 amp** (C) 0.5 amp (D) 2.0 amp (E) 5.0 amp *Resistance of bulbs B & C = 20 Ω combined with D in parallel gives 6.7 Ω for the right side.* *Combined with A & E in series gives a total resistance of 26.7 Ω.* ***E*** *= IR* Which bulb (or bulbs) could burn out without causing other bulbs in the circuit to also go out? **(A) only bulb D** (D) only bulbs C or D (B) only bulb E (E) bulbs B, C, or D (C) only bulbs A or E A and E failing in the main branch would cause the entire circuit to fail. B and C would affect each other.		
72	 In the circuit shown above, the equivalent resistance of the three resistors is (A) 10.5 Ω **(B) 15Ω** (C) 20 Ω (D) 50 Ω (E) 115 Ω The equivalent resistance of the 20 Ω and the 60 Ω in parallel is 15 Ω, added to the 35 Ω resistor in series gives 15 Ω + 35 Ω = 50 Ω	Equivalent	2
83	 Consider the compound circuit shown above. The three bulbs 1, 2, and 3 – represented as resistors in the diagram – are identical. Which of the following statements are true?	Equivalent Power Brightness	2

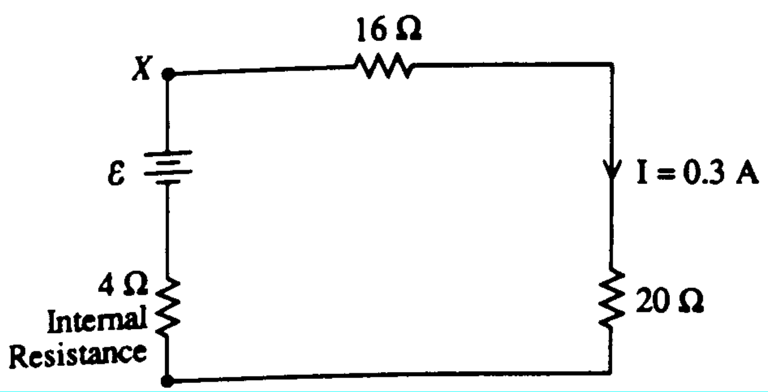
	I. Bulb 3 is brighter than bulb 1 or 2. II. Bulb 3 has more current passing through it than bulb 1 or 2. III. Bulb 3 has a greater voltage drop across it than bulb 1 or 2. (A) I only (B) II only (C) I & II only (D) I & III only **(E) I, II, & III** The current through bulb 3 is twice the current through 1 and 2 since the branch with bulb 3 is half the resistance of the upper branch. The potential difference is the same across each branch, but bulbs 1 and 2 must divide the potential difference between them.		
87	 In the accompanying circuit diagram, the current through the 6.0– Ω resistor is 1.0 A. What is the power supply voltage *V*? (A) 10 V (B) 18 V (C) 24 V **(D) 30 V** (E) 42 V If the current in the 6 Ω resistor is 1 A, then by ratios, the currents in the 2 Ω and 3 Ω resistor are 3 A and 2 A respectively (since they have 1/3 and 1/2 the resistance). This makes the total current 6 A and the potential drop across the 4 Ω resistor 24 V. Now use Kirchhoff's loop rule for any branch	Equivalent Power	2
90	 Given the simple electrical circuit above, if the current in all three resistors is equal, which of the following statements must be true? (A) X, Y, and Z all have equal resistance (B) X and Y have equal resistance **(C) X and Y added together have the same resistance as Z** (D) X and Y each have more resistance than Z (D) none of the above must be true For the currents in the branches to be equal, each branch must have the same resistance	Equivalent	2
92	 The diagram above represents a simple electric circuit composed of 5 identical light bulbs and 2 flashlight cells. Which bulb (or bulbs) would you expect to be the brightest? (A) V only (B) V and W only (C) V and Z only **(D) V, W and Z only** (E) all five bulbs are the same brightness Bulbs in the main branch have the most current through them and are the brightest	Equivalent Power Brightness	2

10 2- 10 4	 An ideal battery, an ideal ammeter, a switch and three resistors are connected as shown. With the switch open as shown in the diagram the ammeter reads 2.0 amperes. With the switch open, what would be the potential difference across the 15 ohm resistor? **(A) 30 V** (B) 40 V (C) 60 V (D) 70 V (E) 110V V = IR With the switch open, what must be the voltage supplied by the battery? (A) 30 V (B) 40 V (C) 60 V **(D) 70 V** (E) 110 V **E** = IR_{total} where R_{total} = 35 Ω When the switch is closed, what would be the current in the circuit? (A) 1.1 A (B) 1.7 A (C) 2.0 A **(D) 2.3 A** (E) 3.0 A With the switch closed, the resistance of the 15 Ω and the 30 Ω in parallel is 10 Ω, making the total circuit resistance 30 Ω and **E** = IR	Equivalent Ammeter Switch	2
10 6- 10 7	 A 9–volt battery is connected to four resistors to form a simple circuit as shown above. How would the current through the 2 ohm resistor compare to the current through the 4 ohm resistor? (A) one–forth as large (D) twice as large (B) one–half as large **(E) equally as large** (C) four times as large The equivalent resistance through path ACD is equal to the equivalent resistance through path ABD, making the current through the two branches equal What would be the potential at point B with respect to point C in the above circuit? (A) +7 V (B) +3 V (C) 0 V **(D) –3 V** (E) –7 V The resistance in each of the two paths is 9 Ω, making the current in each branch 1 A. From point A, the potential drop across the 7 Ω resistor is then 7 V and across the 4 Ω resistor is 4 V, making point B 3 V lower than point C	Equivalent	2

109	 A circuit is connected as shown. All light bulbs are identical. When the switch in the circuit is closed illuminating bulb #4, which other bulb(s) also become brighter? **(A) Bulb #1 only** (B) Bulb #2 only (C) Bulbs #2 and #3 only (D) Bulbs #1, #2, and #3 (E) None of the bulbs. Closing the switch reduces the total resistance of the circuit, increasing the current in the main branch containing bulb 1	Equivalent Power Brighter	2
111-112	The diagram below shows five identical resistors connected in a combination series and parallel circuit to a voltage source.  Through which resistor(s) would there be the greatest current? (A) J only (B) M only (C) N only **(D) J&N only** (E) K&L only Resistors J and N are in the main branch and therefore receive the largest current. Which resistor(s) have the greatest rate of energy dissipation? (A) J only (B) M only (C) N only **(D) J&N only** (E) K&L only $P = I^2R$	Equivalent	2
120	 How many coulombs will pass through the identified resistor in 5 seconds once the circuit was closed? (A) 1.2 (B) 12 (C) 2.4 (D) 24 **(E) 6** The equivalent resistance of the two 4 Ω resistors on the right is 2 Ω making the total circuit resistance 10 Ω and the total current 2.4 A. The 2.4 A will divide equally between the two branches on the right. Q = It = (1.2 A)(5 s) = 6 C	Equivalent	2

59	 If the ammeter in the circuit above reads zero, what is the resistance R ? (A) 1.5 Ω (B) 2 Ω (C) 4 Ω (D) 5 Ω **(E) 6 Ω** For the ammeter to read zero means the junctions at the ends of the ammeter have the same potential. For this to be true, the potential drops across the 1 Ω and the 2 Ω resistor must be equal, which means the current through the 1 Ω resistor must be twice that of the 2 Ω resistor. This means the resistance of the upper branch (1 Ω and 3 Ω) must be ½ that of the lower branch (2 Ω and R) giving 1 Ω + 3 Ω = ½ (2 Ω + R)	Equivalent Ammeter	3
82	When a single resistor is connected to a battery, a total power *P* is dissipated in the circuit. How much total power is dissipated in a circuit if *n* identical resistors are connected in series using the same battery? Assume the internal resistance of the battery is zero. (A) n^2P (B) nP (C) P **(D) P/n** (E) P/n^2 P = E^2/R. Total resistance of n resistors in series is nR making the power P = E^2/nR = P/n	Equivalent Power	3
10	 The total equivalent resistance between points X and Y in the circuit shown above is **(A) 3 Ω** (B) 4 Ω (C) 5 Ω (D) 6 Ω (E) 7 Ω The resistance of the two 2 Ω resistors in parallel is 1 Ω. Added to the 2 Ω resistor in series with the pair gives 3 Ω	Equivalents	
68		Equivalents Combination Ammeter	

	When the switch S is open in the circuit shown above, the reading on the ammeter A is 2.0 A. When the switch is closed, the reading on the ammeter is (A) doubled **(B) increased slightly but not doubled** (C) the same (D) decreased slightly but not halved (E) halved Closing the switch reduces the resistance in the right side from 20 Ω to 15 Ω, making the total circuit resistance decrease from 35 Ω to 30 Ω, a slight decrease, causing a slight increase in current. For the current to double, the total resistance must be cut in half.		
1	 Which two arrangements of resistors shown above have the same resistance between the terminals? (A) I and II **(B) I and IV** (C) II and III (D) II and IV (E) III and IV The resistances are as follows: I: 2 Ω, II: 4 Ω, III: 1 Ω, IV: 2 Ω	Equivalents Series Parallel	1
70	You are given three 1.0 Ω resistors. Which of the following equivalent resistances *CANNOT* be produced using all three resistors? (A) 1/3 Ω (B) 2/3 Ω **(C) 1.0 Ω** (D) 1.5 Ω (E) 3.0 Ω Using all three in series = 3 Ω, all three in parallel = 1/3 Ω. One in parallel with two in series = 2/3 Ω, one in series with two in parallel = 3/2 Ω	Equivalents	2
71	 The figures above show parts of two circuits, each containing a battery of emf ε and internal resistance *r*. The current in each battery is 1 A, but the direction of the current in one battery is opposite to that in the other. If the potential differences across the batteries' terminals are 10 V and 20 V as shown, what are the values of ε and *r*? (A) **E** = 5 V, r = 15 Ω (B) **E** =10 V, r = 100 Ω **(C) E = 15 V, r = 5 Ω** (D) **E** = 20 V, r = 10 Ω (E) The values cannot be computed unless the complete circuits are shown. Summing the potential differences from bottom to top: left circuit: – (1 A)r + **E** = 10 V right circuit: + (1 A)r + **E** = 20 V, solve simultaneous equation	Internal resistance	

<table>
<tr>
<td>17-19</td>
<td>


The above circuit diagram shows a battery with an internal resistance of 4.0 ohms connected to a 16–ohm and a
20–ohm resistor in series. The current in the 20–ohm resistor is 0.3 amperes
What is the emf of the battery?
(A) 1.2 V (B) 6.0 V (C) 10.8 V **(D) 12.0 V** (E) 13.2 V
Total circuit resistance (including internal resistance) = 40 Ω; total current = 0.3 A. ***E*** *= IR*
What is the potential difference across the terminals X and Y of the battery?
(A) 1.2 V (B) 6.0 V **(C) 10.8 V** (D) 12.0 V (E) 13.2 V
V_{XY} = **E** – Ir where r is the internal resistance

What power is dissipated by the 4–ohm internal resistance of the battery?
(A) 0.36 W (B) 1.2 W (C) 3.2 W (D) 3.6 W (E) 4.8 W
$P = I^2r$
</td>
<td>Internal Resistance</td>
<td>2</td>
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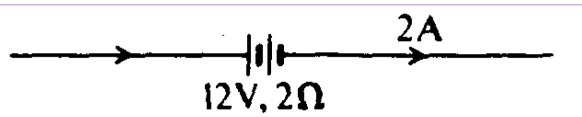
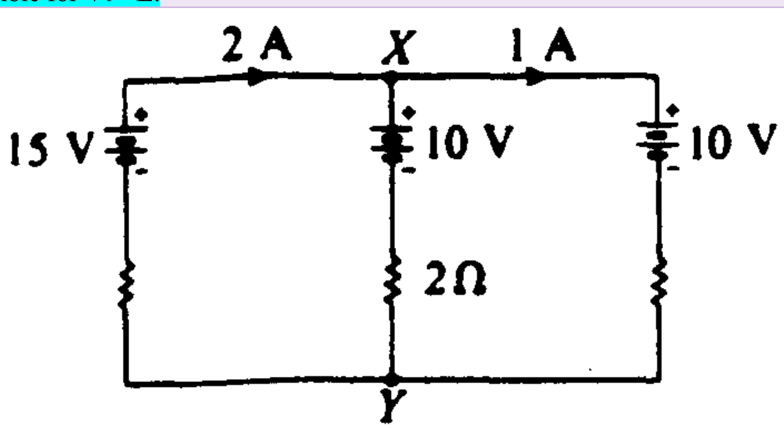
<tr>
<td>35</td>
<td>


A 12–volt storage battery, with an internal resistance of 2 Ω, is being charged by a current of 2 amperes as
shown in the diagram above. Under these circumstances, a voltmeter connected across the terminals of the
battery will read
(A) 4 V (B) 8 V (C) 10 V (D) 12 V **(E) 16 V**

Summing the potential differences from left to right gives V_T = –12 V – (2 A)(2 Ω) = – 16 V. It
is possible for V_T > **E**.
</td>
<td>Internal resistance voltmeter</td>
<td>2</td>
</tr>
<tr>
<td>41</td>
<td>


In the circuit shown above, the emf's of the batteries are given, as well as the currents in the outside branches
and the resistance in the middle branch. What is the magnitude of the potential difference between X and Y?
(A) 4 V (B) 8 V (C) 10 V **(D) 12 V** (E) 16 V

Kirchhoff's junction rule applied at point X gives 2 A = I + 1 A, so the current in the
</td>
<td>Kichoff's</td>
<td></td>
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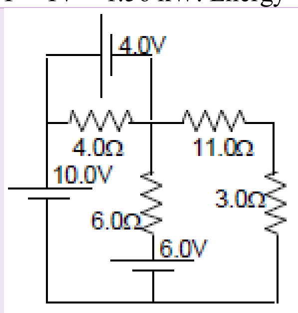
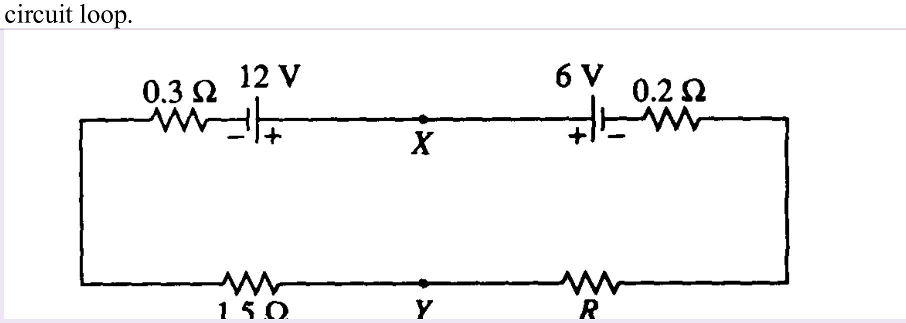
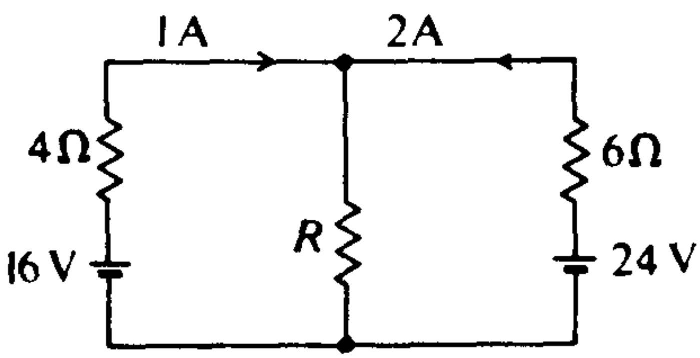
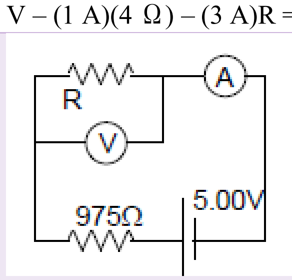
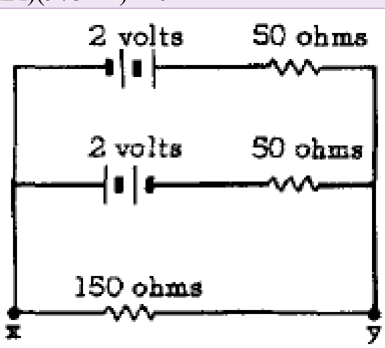
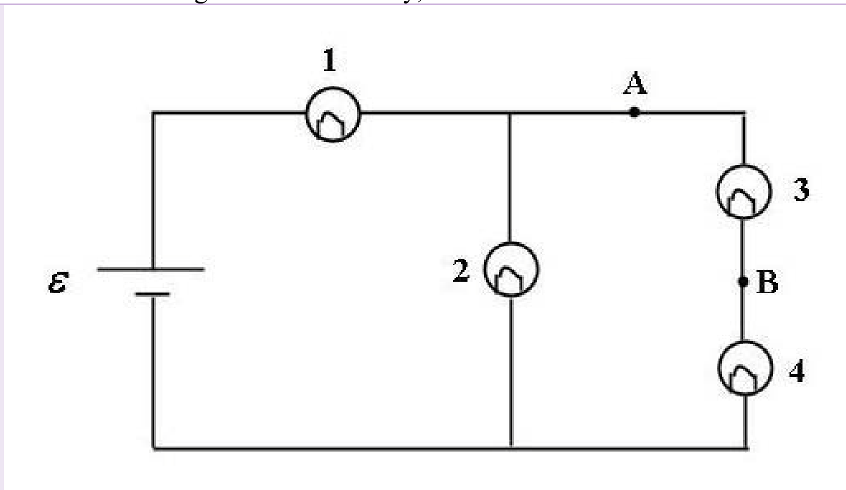
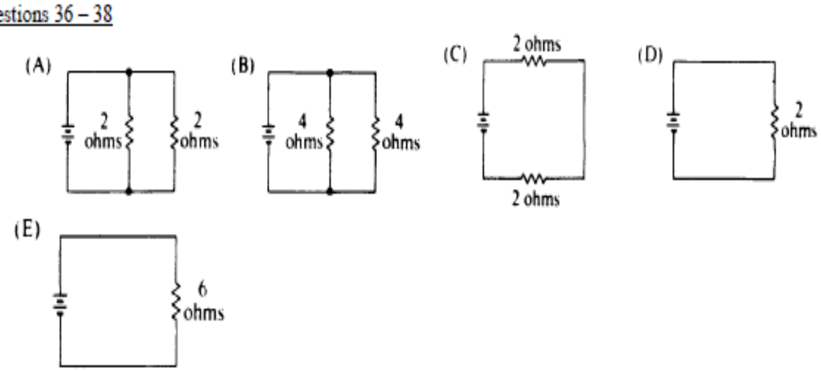
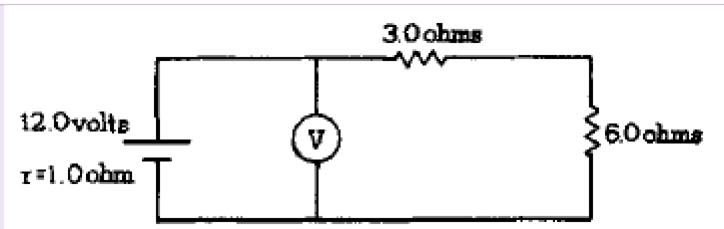
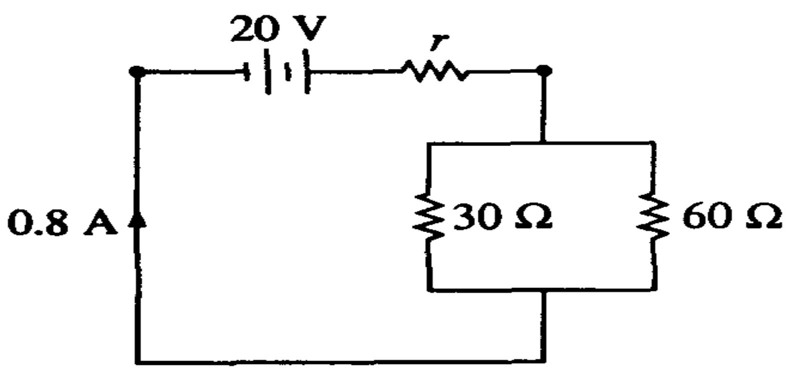
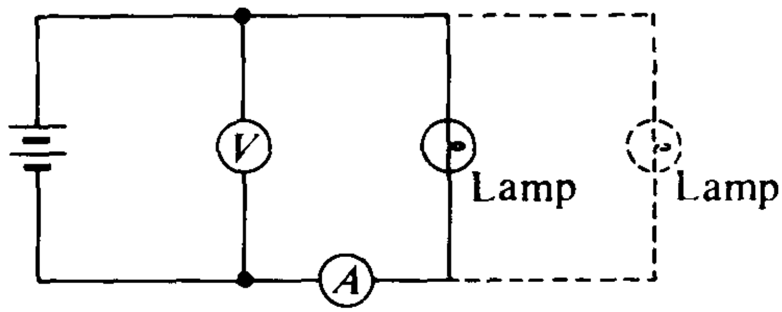
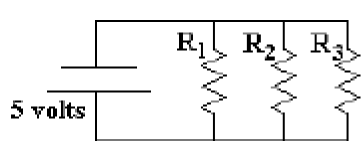
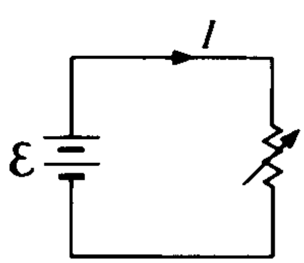
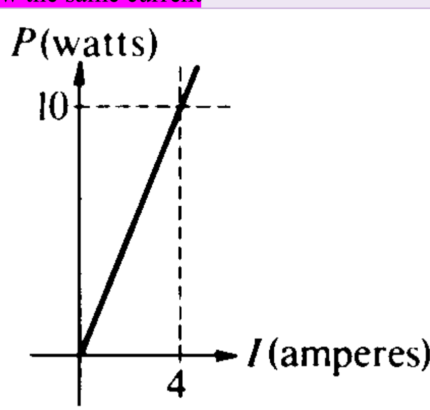
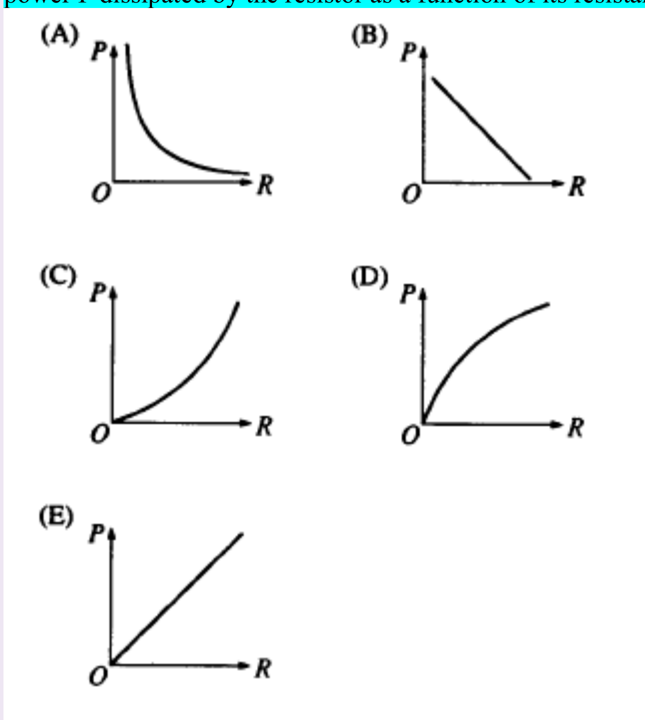
	middle wire is 1 A. Summing the potential differences through the middle wire from X to Y gives – 10 V – (1 A)(2 Ω) = –12 V		
24	A certain coffeepot draws 4.0 A of current when it is operated on 120 V household lines. If electrical energy costs 10 cents per kilowatt–hour, how much does it cost to operate the coffeepot for 2 hours? (A) 2.4 cents (B) 4.8 cents (C) 8.0 cents **(D) 9.6 cents** (E) 16 cents. Power = IV = 480 W = 0.48 kW. Energy = Pt = (0.48 kW)(2 hours) = 0.96 kW-h	Kilowatt hours	
99	An electric heater draws 13 amperes of current when connected to 120 volts. If the price of electricity is \$0.10/kWh, what would be the approximate cost of running the heater for 8 hours? (A) \$0.19 (B) \$0.29 (C) \$0.75 **(D) \$1.25** (E) \$1.55 P = IV = 1.56 kW. Energy = Pt = 1.56 kW × 8 h = 12.48 kW-h	Kilowatt Hours	1
73	 What is the current through the 6.0 Ω resistor shown in the accompanying circuit diagram? Assume all batteries have negligible resistance. **(A) 0** (B) 0.40 A (C) 0.50 A (D) 1.3 A (E) 1.5 A If you perform Kirchhoff's loop rule for the highlighted loop, you get a current of 0 A through the 6 Ω resistor	Kirchhoff	2
14	Kirchhoff's loop rule for circuit analysis is an expression of which of the following? (A) Conservation of charge **(B) Conservation of energy** (C) Ampere's law (D) Faraday's law (E) Ohm's law The loop rule involves the potential and energy supplied by the battery and it's use around a circuit loop.	Kirchhoff's	
52-54	 In the circuit above, the emf's and the resistances have the values shown. The current I in the circuit is 2 amperes. The resistance R is **(A) 1 Ω** (B) 2 Ω (C) 3 Ω (D) 4 Ω (E) 6 Ω *Utilizing Kirchhoff's loop rule starting at the upper left and moving clockwise: – (2 A)(0.3 Ω) + 12 V – 6 V – (2 A)(0.2 Ω) – (2A)(R) – (2A)(1.5 Ω) = 0*	Kirchhoff's Ohm's Law Power	

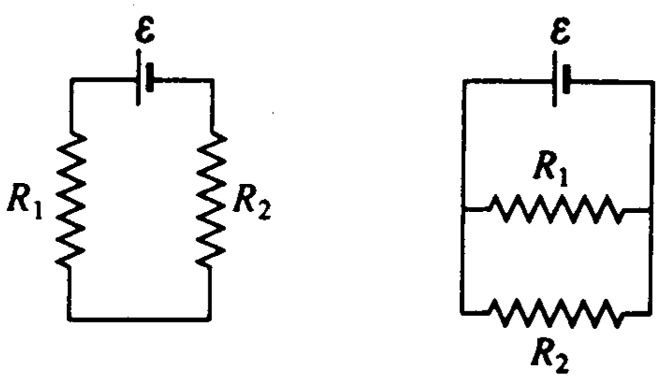
	The potential difference between points X and Y is (A) 1.2 V (B) 6.0 V **(C) 8.4 V** (D) 10.8 V (E) 12.2 V *Summing the potential differences: – 6 V – (2 A)(0.2 Ω) – (2A)(1 Ω) = – 8.4 V* How much energy is dissipated by the 1.5–ohm resistor in 60 seconds? (A) 6 J (B) 180 J **(C) 360 J** (D) 720 J (E) 1,440 J *Energy = Pt =* I_2Rt		
33	 In the circuit shown above, what is the resistance R? (A) 3 Ω **(B) 4 Ω** (C) 6 Ω (D) 12 Ω (E) 18 Ω The current through R is found using the junction rule at the top junction, where 1 A + 2 A enter giving I = 3 A. Now utilize Kirchhoff's loop rule through the left or right loops: (left side) + 16 V – (1 A)(4 Ω) – (3 A)R = 0 giving R = 4 Ω	Kirchhoff's	2
78	 The voltmeter in the accompanying circuit diagram has internal resistance 10.0 kΩ and the ammeter has internal resistance 25.0 Ω. The ammeter reading is 1.00 mA. The voltmeter reading is most nearly: (A) 1.0 V (B) 2.0 V (C) 3.0 V **(D) 4.0 V** (E) 5.0 V Using Kirchhoff's loop rule around the circuit going through either V or R since they are in parallel and will have the same potential drop gives: – V – (1.00 mA)(25 Ω) + 5.00 V – (1.00 mA)(975 Ω) = 0	Kirchhoff's Voltmeter Ammeters	2
34	 In the circuit shown above, the current in each battery is 0.04 ampere. What is the potential difference between	Kirchhoff's	3

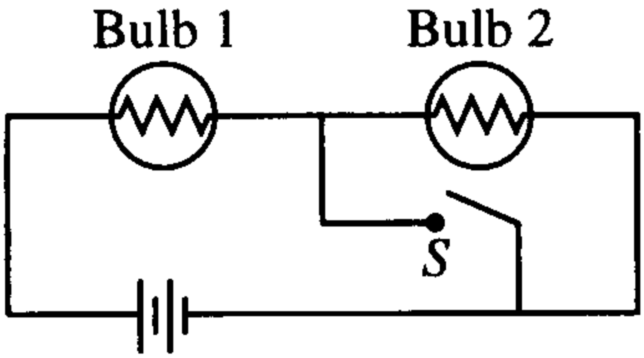
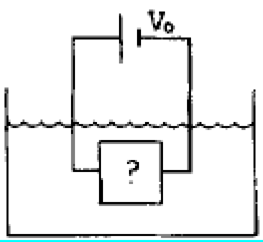
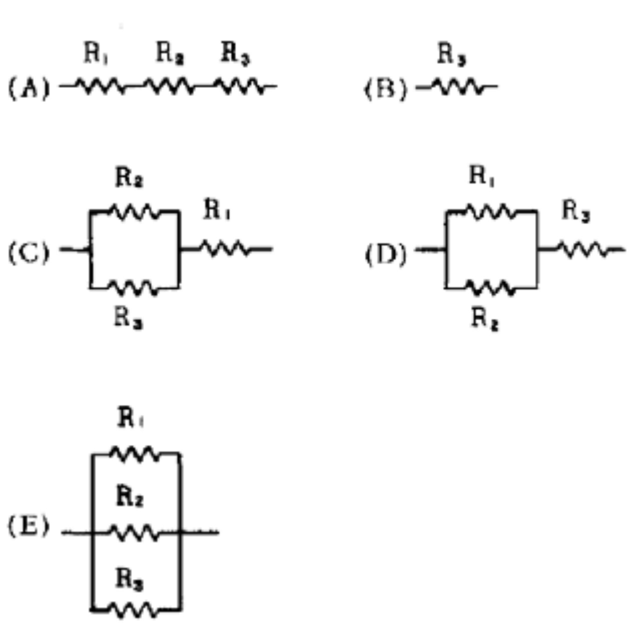
	the points x and y? (A) 8 V (B) 2 V (C) 6 V **(D) 0 V** (E) 4 V Utilizing Kirchhoff's loop rile with any loop including the lower branch gives 0 V since the resistance next to each battery drops the 2 V of each battery leaving the lower branch with no current. You can also think of the junction rule where there is 0.04 A going into each junction and 0.04 A leaving to the other battery, with no current for the lower branch.		
11 8	 For the circuit shown, a shorting wire of negligible resistance is added to the circuit between points A and B. When this shorting wire is added, bulb #3 goes out. Which bulbs (all identical) in the circuit brighten? (A) Only Bulb 2 (B) Only Bulb 4 **(C) Only Bulbs 1 and 4** (D) Only Bulbs 2 and 4 (E) Bulbs 1, 2 and 4 Shorting bulb 3 decreases the resistance in the right branch, increasing the current through bulb 4 and decreasing the total circuit resistance. This increases the total current in the main branch containing bulb 1.	Ohm's Shorting	
36- 38	Questions 36 – 38  The batteries in each of the circuits shown above are identical and the wires have negligible resistance. 36. In which circuit is the current furnished by the battery the greatest? **(A)A** (B)B (C)C (D)D (E) E *Current is greatest where resistance is least. The resistances are, in order, 1 Ω, 2 Ω, 4 Ω , 2 Ω and 6 Ω.* 37. In which circuit is the equivalent resistance connected to the battery the greatest? (A)A (B)B (C)C (D)D **(E) E** ***See Above*** 38. Which circuit dissipates the least power? (A)A (B)B (C)C (D)D **(E) E**	Ohm's Equivalent Power	1

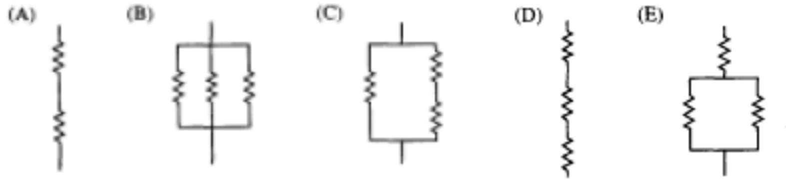
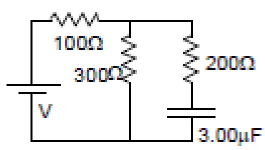
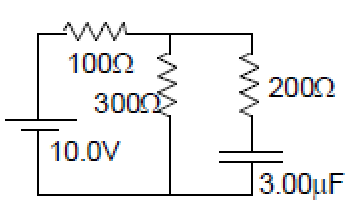
	*Least power is for the greatest resistance (P = **E**2/R)*		
115	 In the circuit above the voltmeter V draws negligible current and the internal resistance of the battery is 1.0 ohm. The reading of the voltmeter is (A) 10.5 V (B) 12.0 V **(C) 10.8 V** (D) 13.0 V (E) 11.6 V With a total resistance of 10 Ω, the total current is 1.2 A. The terminal voltage V_T = **E** – Ir	Ohm's Voltmeter Internal resistance	1
57	 A 30–ohm resistor and a 60–ohm resistor are connected as shown above to a battery of emf 20 volts and internal resistance *r*. The current in the circuit is 0.8 ampere. What is the value of *r*? (A) 0.22 Ω (B) 4.5 Ω **(C) 5 Ω** (D) 16 Ω (E) 70 Ω Total resistance = **E**/I = 25 Ω. Resistance of the 30 Ω and 60 Ω resistors in parallel = 20 Ω adding the internal resistance in series with the external circuit gives R_{total}= 20 Ω + r = 25 Ω	Ohm's Law Equivalent	
93	Three different resistors R_1, R_2 and R_3 are connected in parallel to a battery. Suppose R_1 has 2 V across it, R_2 =4 Ω, and R_3 dissipates 6 W. What is the current in R_3? (A) 0.33 A (B) 0.5 A (C) 2 A **(D) 3 A** (E) 12 A In parallel, all the resistors have the same voltage (2 V). $P_3 = I_3V_3$	Ohm's Law	
13	Which of the following will cause the electrical resistance of certain materials known as superconductors to suddenly decrease to essentially zero? (A) Increasing the voltage applied to the material beyond a certain threshold voltage (B) Increasing the pressure applied to the material beyond a certain threshold pressure **(C) Cooling the material below a certain threshold temperature** (D) Stretching the material to a wire of sufficiently small diameter (E) Placing the material in a sufficiently large magnetic field Resistance varies directly with temperature. Superconductors have a resistance that quickly goes to zero once the temperature lowers beyond a certain threshold.	Other Superconductors	
29	The operating efficiency of a 0.5 A, 120 V electric motor that lifts a 9 kg mass against gravity at an average velocity of 0.5 m/s is most nearly	Other Efficiency	

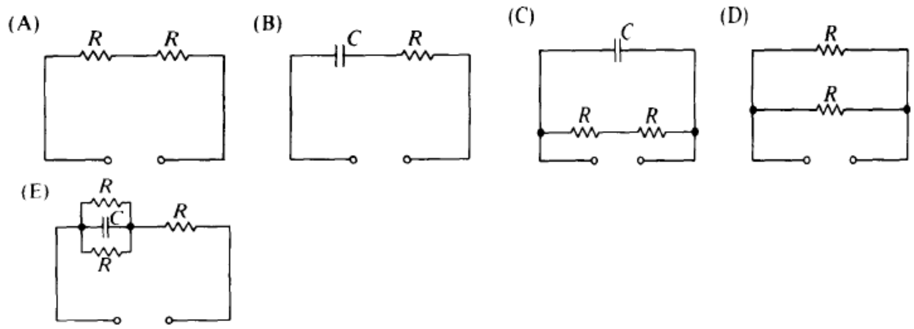
	(A) 7% (B) 13% (C) 25% (D) 53% **(E) 75 %** The motor uses P = IV = 60 W of power but only delivers P = Fv = mgv = 45 W of power. The efficiency is "what you get" ÷ "what you are paying for" = 45/60		
3	 A lamp, a voltmeter V, an ammeter A, and a battery with zero internal resistance are connected as shown above. Connecting another lamp in parallel with the first lamp as shown by the dashed lines would **(A) increase the ammeter reading** (B) decrease the ammeter reading (C) increase the voltmeter reading (D) decrease the voltmeter reading (E) produce no change in either meter reading Adding resistors in parallel decreases the total circuit resistance, this increasing the total current in the circuit	Parallel Volts Ammeter Voltmeter	2
94	 Which of the following statements is NOT true concerning the simple circuit shown where resistors R_1, R_2 and R_3 all have equal resistances? (A) the largest current will pass through R_1 (B) the voltage across R_2 is 5 volts (C) the power dissipated in R_3 could be 10 watts (D) if R_2 were to burn out, current would still flow through both R_1 and R_3 (E) the net resistance of the circuit is less than R_1 Answer: A If the resistances are equal, they will all draw the same current	Parallel Ohm's	2
8	  The circuit shown above left is made up of a variable resistor and a battery with negligible internal resistance. A graph of the power P dissipated in the resistor as a function of the current I supplied by the battery is given	Power Variable Resistor	

	above right. What is the emf of the battery? (A) 0.025 V (B) 0.67 V **(C) 2.5 V** (D) 6.25 V (E) 40 V P = I**E**		
9	An immersion heater of resistance R converts electrical energy into thermal energy that is transferred to the liquid in which the heater is immersed. If the current in the heater is I, the thermal energy transferred to the liquid in time t is (A) IRt **(B) I^2Rt** (C) IR^2t (D) IRt^2 (E) IR/t $W = Pt = I^2Rt$	Power Thermal	
47	The power dissipated in a wire carrying a constant electric current I may be written as a function of the length l of the wire, the diameter d of the wire, and the resistance ρ of the material in the wire. In this expression, the power dissipated is directly proportional to which of the following? (A) l only (B) d only (C) l and ρ only (D) d and ρ only (E) l, d, and ρ $P = I_2R$ and $R = \rho L/A$ giving $P \propto \rho L/d_2$	Power Resistance	
58	A variable resistor is connected across a constant voltage source. Which of the following graphs represents the power P dissipated by the resistor as a function of its resistance R?  Answer: A $P = V_2/R$ and if V is constant $P \propto 1/R$	Power Graphs	
67	A hair dryer is rated as 1200 W, 120 V. Its effective internal resistance is (A) 0.1 Ω (B) 10 Ω **(C) 12 Ω** (D) 120 Ω (E) 1440 Ω $P = V_2/R$	Power Ohm's Internal resistance	
32	When lighted, a 100–watt light bulb operating on a 110–volt household circuit has a resistance closest to (A) 10_{-2} Ω (B) 10_{-1} Ω (C) 1 Ω (D) 10 Ω **(E) 100 Ω** $P = V^2/R$	Power	1
86	A heating coil is rated 1200 watts and 120 volts. What is the maximum value of the current under these	Power	1

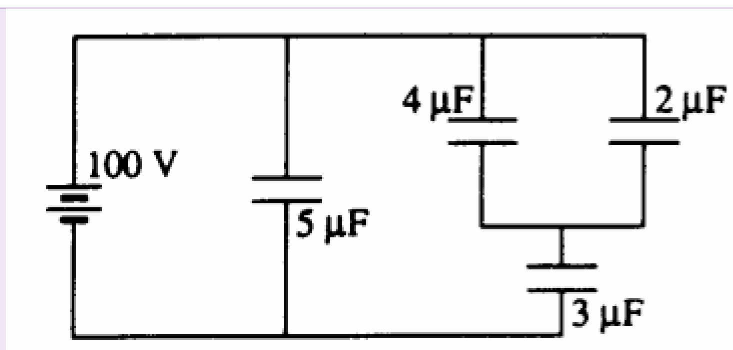
	conditions? **(A) 10.0 A** (B) 12.0 A (C) 14.1 A (D) 0.100 A (E) 0.141 A P = IV		
89	What is the resistance of a 60 watt light bulb designed to operate at 120 volts? (A) 0.5 Ω (B) 2 Ω (C) 60 Ω **(D) 240 Ω** (E) 7200 Ω $P = V^2/R$	Power	1
105	How much current flows through a 4 ohm resistor that is dissipating 36 watts of power? (A) 2.25 amps **(B) 3.0 amps** (C) 4.24 amps (D) 9.0 amps (E) 144 amps $P = I^2R$	Power	1
117	A household iron used to press clothes is marked “120 volt, 600 watt.” In normal use, the current in it is (A) 0.2 A (B) 2 A (C) 4 A **(D) 5 A** (E) 7.2 A P = IV	Power	1
20	 Series Connection Parallel Connection In the diagrams above, resistors R_1 and R_2 are shown in two different connections to the same source of emf ε that has no internal resistance. How does the power dissipated by the resistors in these two cases compare? (A) It is greater for the series connection. **(B) It is greater for the parallel connection.** (C) It is the same for both connections. (D) It is different for each connection, but one must know the values of R_1 and R_2 to know which is greater. (E) It is different for each connection, but one must know the value of ε to know which is greater. With more current drawn from the battery for the parallel connection, more power is dissipated in this connection. While the resistors in series share the voltage of the battery, the resistors in parallel have the full potential difference of the battery across them.	Power Internal resistance emf	2
48	A wire of resistance *R* dissipates power *P* when a current *I* passes through it. The wire is replaced by another wire with resistance *3R*. The power dissipated by the new wire when the same current passes through it is (A) P/9 (B) P/3 (C) P **(D) 3P** (E) 6P $P = I^2R$	Power	2

65	 The circuit in the figure above contains two identical lightbulbs in series with a battery. At first both bulbs glow with equal brightness. When switch S is closed, which of the following occurs to the bulbs? Bulb I — Bulb 2 (A) Goes out — Gets brighter (B) Gets brighter — Goes out (C) Gets brighter — Gets slightly dimmer (D) Gets slightly dimmer — Gets brighter (E) Nothing — Goes out Answer: B Closing the switch short circuits Bulb 2 causing no current to flow to it. Since the bulbs were originally in series, this decreases the total resistance and increases the total current, making bulb 1 brighter.	Power Brighter Dimmer	2
116	 Suppose you are given a constant voltage source V_0 and three resistors R_1, R_2, and R_3 with $R_1 > R_2 > R_3$. If you wish to heat water in a pail which of the following combinations of resistors will give the most rapid heating?  Answer: E	Power	2

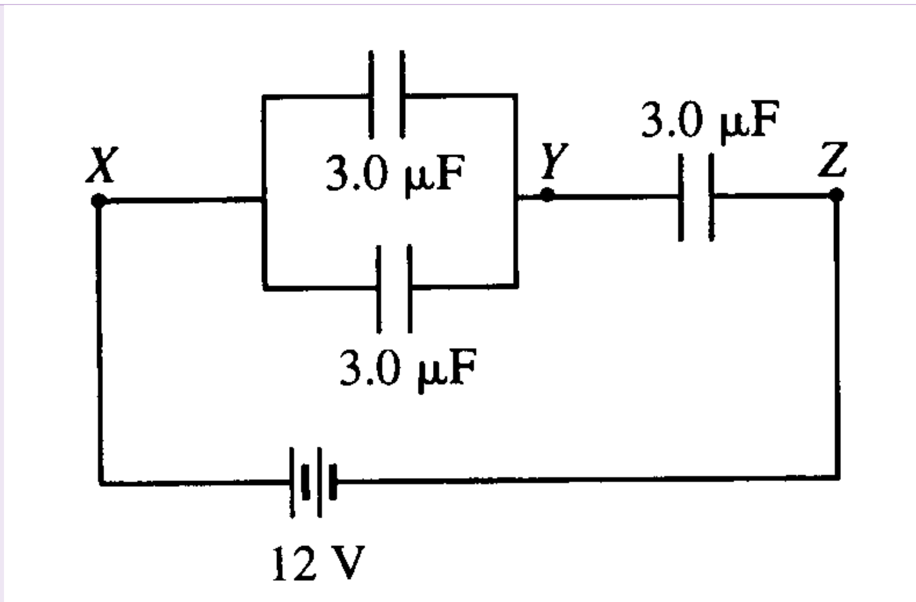
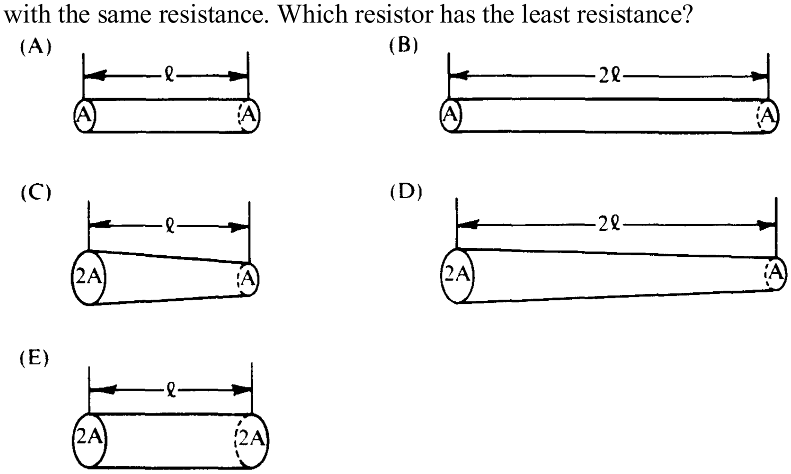
	Most rapid heating requires the largest power dissipation. This occurs with the resistors in parallel.		
61	Which of the following combinations of 4 Ω resistors would dissipate 24 W when connected to a 12 Volt battery?  To dissipate 24 W means R = V2/P = 6 Ω. The resistances, in order, are: 8 Ω, 4/3 Ω, 8/3 Ω, 12 Ω and 6 Ω	Power Equivalent	3
62	A narrow beam of protons produces a current of 1.6×10^{-3} A. There are 10^9 protons in each meter along the beam. Of the following, which is the best estimate of the average speed of the protons in the beam? (A) 10^{-15} m/s (B) 10^{-12} m/s (C) 10^{-7} m/s (D) 10^7 m/s (E) 10^{12} m/s Answer:D Dimensional analysis: 1.6×10^{-3} A = 1.6×10^{-3} C/s ÷ 1.6×10^{-19} C/proton = 10^{16} protons/sec ÷ 10^9 protons/meter = 10^7 m/s	Random	
88	 In the circuit diagrammed above, the 3.00– μ F capacitor is fully charged at 18.0 μ C. What is the value of the power supply voltage *V*? (A) 4.40 V (B) 6.00 V **(C) 8.00 V** (D) 10.4 V (E) 11.0 V The voltage across the capacitor is 6 V (Q = CV) and since the capacitor is in parallel with the 300 Ω resistor, the voltage across the 300 Ω resistor is also 6 V. The 200 Ω resistor is not considered since the capacitor is charged and no current flows through that branch. The 100 Ω resistor in series with the 300 Ω resistor has 1/3 the voltage (2 V) since it is 1/3 the resistance. Kirchhoff's loop rule for the left loop gives **E** = 8 V.	RC Cicruits	
80	 See the accompanying figure. What is the current through the 300 Ω resistor when the capacitor is fully charged? (A) zero (B) 0.020 A (C) 0.025 A (D) 0.033 A (E) 0.100 A When the capacitor is fully charged, the branch on the right has no current, effectively making the circuit a series circuit with the 100 Ω and 300 Ω resistors. R_{total}= 400 Ω, **E** = 10 V = IR	R-C circuit	
6-7	The five incomplete circuits below are composed of resistors R, all of equal resistance, and	RC circuits	

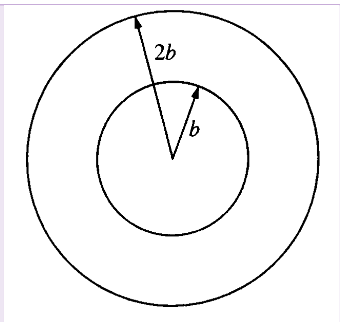
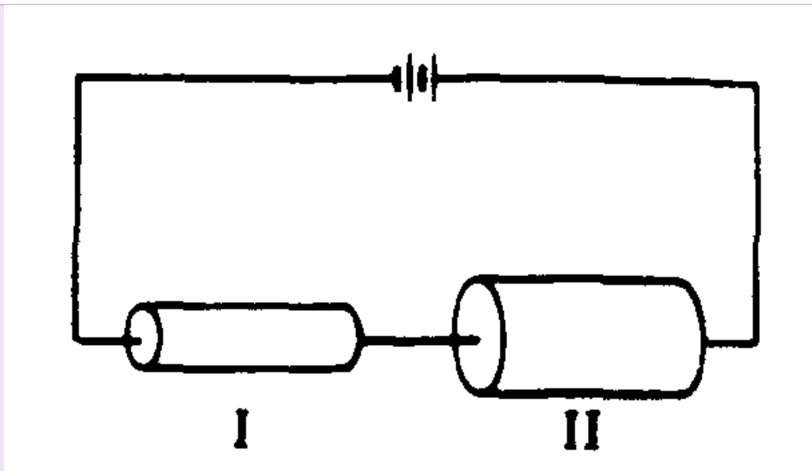
<table>
<tr><td></td><td>capacitors C, all of
equal capacitance. A battery that can be used to complete any of the circuits is available.

6. Into which circuit should the battery be connected to obtain the greatest steady power dissipation?
(A) A (B) B (C) C (D) D (E) E
For steady power dissipation, the circuit must allow current to slow indefinitely. For the greatest
power, the total resistance should be the smallest value. These criteria are met with the resistors
in parallel.

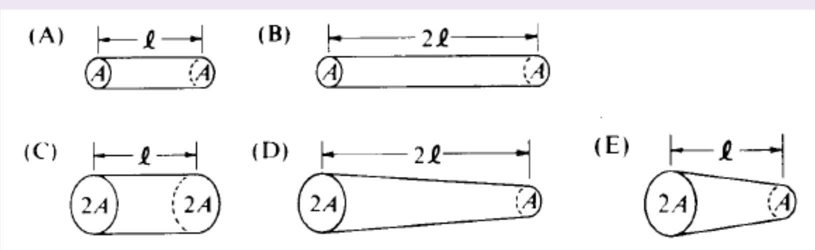
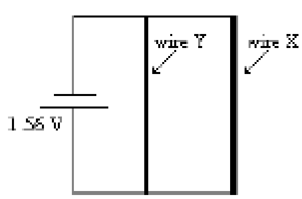
7. Which circuit will retain stored energy if the battery is connected to it and then disconnected?
(A) A (B) B (C) C (D) D (E) E

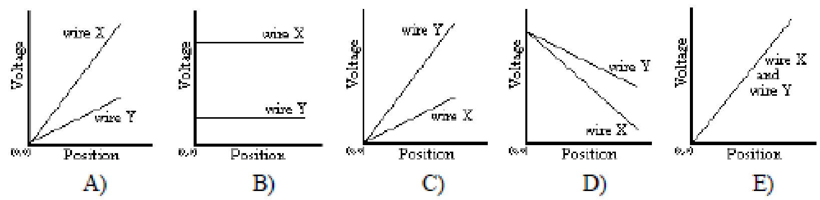
To retain energy, there must be a capacitor that will not discharge through a resistor. Capacitors
in circuits C and E will discharge through the resistors in parallel with them.</td><td></td><td></td></tr>
<tr><td>15-16</td><td>
The equivalent capacitance for this network is most nearly
(A) 10/7 μF (B) 3/2 μF (C) 7/3 μF (D) 7 μF (E) 14 μF
The capacitance of the 4 μF and 2 μF in parallel is 6 μF. Combined with the 3 μF in series gives 2
μF for the right branch. Added to the 5 μF in parallel gives a total of 7 μF

The charge stored in the 5–microfarad capacitor is most nearly
(A) 360 μC (B) 500 μC (C) 710 μC (D) 1,100 μC (E) 1,800 μC
Since the 5 μF capacitor is in parallel with the battery, the potential difference across it is 100 V.
Q = CV</td><td>RC Circuits</td><td></td></tr>
<tr><td>60</td><td>A resistor R and a capacitor C are connected in series to a battery of terminal voltage V_0. Which of the following equations relating the current I in the circuit and the charge Q on the capacitor describes this circuit?
(A) $V_0 + QC - I^2R = 0$ (B) $V_0 - Q/C - IR = 0$ (C) $V_0^2 - Q^2/2C - I^2R = 0$
(D) $V_0 - CI - I^2R = 0$ (E) $Q/C - IR = 0$
Answer: B
Kirchhoff's loop rule (V = Q/C for a capacitor)</td><td>RC Circuits</td><td></td></tr>
</table>

64	 Three identical capacitors, each of capacitance 3.0 μ F, are connected in a circuit with a 12 V battery as shown above. The equivalent capacitance between points X and Z is (A) 1.0 μ F (B) 2.0 μ F (C) 4.5 μ F (D) 6.0 μ F (E) 9.0 μ F *The equivalent capacitance of the two 3 μ F capacitors in parallel is 6 μ F, combined with the 3 μ F in series gives C_{total} = 2 μ F* The potential difference between points Y and Z is (A) zero (B) 3 V (C) 4 V **(D) 8 V** (E) 9 V *The equivalent capacitance between X and Y is twice the capacitance between Y and Z. This* *means the voltage between X and Y is ½ the voltage between Y and Z. For a total of 12 V, this* *gives 4 V between X and Y and 8 V between Y and Z.*	RC Circuits	
11	The five resistors shown below have the lengths and cross–sectional areas indicated and are made of material with the same resistance. Which resistor has the least resistance?  Answer: E R = ρ L/A. Least resistance is the widest, shortest resistor	Resistance	2

26	 Two concentric circular loops of radii *b* and *2b*, made of the same type of wire, lie in the plane of the page, as shown above. The total resistance of the wire loop of radius *b* is *R*. What is the resistance of the wire loop of radius *2b*? (A) *R/4* (B) *R/2* (C) *R* **(D) *2R*** (E) *4R* The larger loop, with twice the radius, has twice the circumference (length) and R = ρ L/A	Resistance	2
28	A wire of length *L* and radius *r* has a resistance *R*. What is the resistance of a second wire made from the same material that has a length *L/2* and a radius *r/2*? (A) *4R* **(B) *2R*** (C) *R* (D) *R/2* (E) *R/4* R = ρ L/A. If L ÷ 2, R ÷ 2 and is r ÷ 2 then A ÷ 4 and R × 4 making the net effect R ÷ 2 × 4	Resistance	2
49	 Two resistors of the same length, both made of the same material, are connected in a series to a battery as shown above. Resistor II has a greater cross. sectional area than resistor I. Which of the following quantities has the same value for each resistor? (A) Potential difference between the two ends (B) Electric field strength within the resistor (C) Resistance (D) Current per unit area **(E) Current** Since these resistors are in series, they must have the same current	Resistance Ohm's Law	2
69	Two conducting cylindrical wires are made out of the same material. Wire X has twice the length and twice the diameter of wire Y. What is the ratio R_x/R_y (A) 1/4 **(B) ½** (C) 1 (D) 2 (E) 4 $R = \rho L/A \propto L/d^2$ where d is the diameter. $R_x/R_y = L_x/d_x^2 \div L_y/d_y^2 = (2L_y)d_y^2/[L_y(2d_y)^2] = ½$	Resistance	2
85	Wire I and wire II are made of the same material. Wire II has twice the diameter and twice the length of wire I.	Resistance	2

	If wire I has resistance *R*, wire II has resistance (A) *R*/8 (B) *R*/4 **(C) *R*/2** (D) *R* (E) 2*R* $R = \rho L/A \propto L/d^2$ where d is the diameter. $R_{II}/R_I = L_{II}/d_{II}^2 \div L_I/d_I^2 = (2L_I)d_I^2/[L_I(2d_I)^2] = ½$		
91	Wire Y is made of the same material but has twice the diameter and half the length of wire X. If wire X has a resistance of *R* then wire Y would have a resistance of **(A) *R/*8** (B) *R*/2 (C) *R* (D) 2*R* (E) 8*R* $R \propto L/A = L/d^2$. If d × 2, R ÷ 4 and if L ÷ 2, R ÷ 2 making the net effect R ÷ 8	Resistance	2
108	A cylindrical resistor has length *L* and radius *r*. This piece of material is then drawn so that it is a cylinder with new length 2*L*. What happens to the resistance of this material because of this process? (A) the resistance is quartered. (B) the resistance is halved. (C) the resistance is unchanged. (D) the resistance is doubled. **(E) the resistance is quadrupled.** Since the volume of material drawn into a new shape in unchanged, when the length is doubled, the area is halved. $R = \rho L/A$	Resistance	2
110	A cylindrical graphite resistor has length L and cross–sectional area A. It is to be placed into a circuit, but it first must be cut in half so that the new length is ½ L. What is the ratio of the new resistance to the old resistance of the cylindrical resistor? (A) 4 (B) 2 **(C) 1** (D) ½ (E) ¼ *Resistance* is dependent on the material. Not to be confused with *resistance*	Resistance	2
4	The five resistors shown below have the lengths and cross–sectional areas indicated and are made of material with the same resistance. Which has the greatest resistance?  Answer: B $R = \rho L/A$. Greatest resistance is the longest, narrowest resistor.	Resistance Varying diameter	3
96	 The following diagram represents an electrical circuit containing two uniform resistance wires connected to a single flashlight cell. Both wires have the same length, but the thickness of wire X is twice that of wire Y. Which of the following would best represent the dependence of electric potential on position along the length of the two wires?	Resistance Graphs	3

	 Answer: E Even though the wires have different resistances and currents, the potential drop across each is 1.56 V and will vary by the same gradient, dropping all 1.56 V along the same length.		
11 4	A current through the thin filament wire of a light bulb causes the filament to become white hot, while the larger wires connected to the light bulb remain much cooler. This happens because (A) the larger connecting wires have more resistance than the filament. **(B) the thin filament has more resistance than the larger connecting wires.** (C) the filament wire is not insulated. (D) the current in the filament is greater than that through the connecting wires. (E) the current in the filament is less than that through the connecting wires. In series circuits, larger resistors develop more power	Resistance	3
97	Each member of a family of six owns a computer rated at 500 watts in a 120 V circuit. If all computers are plugged into a single circuit protected by a 20 ampere fuse, what is the maximum number of the computers can be operating at the same time? (A) 1 (B) 2 (C) 3 **(D) 4** (E) 5 or more Each computer draws I = P/V = 4.17 A. 4 computers will draw 16.7 A, while 5 will draw over 20 A.	Safety device Fuse Power	
21	The product (2 amperes × 2 volts × 2 seconds) is equal to (A) 8 coulombs (B) 8 newtons **(C) 8 joules** (D) 8 calories (E) 8 newton–amperes Amperes = I (current); Volts = V (potential difference); Seconds = t (time): IVt = energy	Units	2