ANSWERS - AP Physics Multiple Choice Practice – Circuits

	Solution	Answer
1.	The resistances are as follows: I: 2 Ω, II: 4 Ω, III: 1 Ω, IV: 2 Ω	B
2.	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 $\mathcal{E}/R$ = 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.	B
3.	Adding resistors in parallel decreases the total circuit resistance, this increasing the total current in the circuit.	A
4.	$R = \rho L/A$. Greatest resistance is the longest, narrowest resistor.	B
5.	In parallel $V_1 = V_2$. $Q_1 = C_1V_1$ and $Q_2 = C_2V_2$ so $Q_1/Q_2 = C_1/C_2 = 1.5$	D
6.	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.	D
7.	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.	B
8.	$P = I\mathcal{E}$	C
9.	$W = Pt = I^2Rt$	B
10.	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	A
11.	$R = \rho L/A$. Least resistance is the widest, shortest resistor	E
12.	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 $\mathcal{E}/I$ = (10 V)/(0.5 A) = 20 Ω = 10 Ω + r/2	E
13.	Resistance varies directly with temperature. Superconductors have a resistance that quickly goes to zero once the temperature lowers beyond a certain threshold.	C
14.	The loop rule involves the potential and energy supplied by the battery and it’s use around a circuit loop.	B
15.	The capacitance of the 4 μF and 2μF in parallel is 6 μF. Combined with the 3μF in series gives 2 μF for the right branch. Added to the 5 μF in parallel gives a total of 7 μF	D
16.	Since the 5 μF capacitor is in parallel with the battery, the potential difference across it is 100 V. Q = CV	B
17.	Total circuit resistance (including internal resistance) = 40 Ω; total current = 0.3 A. $\mathcal{E} = IR$	D
18.	$V_{XY} = \mathcal{E} - Ir$ where r is the internal resistance	C
19.	$P = I^2r$	A
20.	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.	B
21.	Amperes = I (current); Volts = V (potential difference); Seconds = t (time): IVt = energy	C

22. 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. A

23. The upper branch, with twice the resistance of the lower branch, will have ½ the current of the lower branch. C

24. Power = IV = 480 W = 0.48 kW. Energy = Pt = (0.48 kW)(2 hours) = 0.96 kW-h D

25. Total circuit resistance of the load = R/2. Total circuit resistance including the internal resistance = r + R/2. The current is then $\mathcal{E}/(r + R/2)$ and the total power dissipated in the load is $P = I^2R_{load} = (\mathcal{E}^2R/2)/(r + R/2)^2$. Using calculus max/min methods or plotting this on a graph gives the value of R for which this equation is maximized of R = 2r. This max/min problem is not part of the B curriculum but you should be able to set up the equation to be maximized. D

26. The larger loop, with twice the radius, has twice the circumference (length) and R = ρL/A D

27. By process of elimination, A is the only possible true statement. A

28. R = ρL/A. If L ÷ 2, R ÷ 2 and is r ÷ 2 then A ÷ 4 and R × 4 making the net effect R ÷ 2 × 4 B

29. 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 E

30. Resistance of the 2000 Ω and 6000 Ω in parallel = 1500 Ω, adding the 2500 Ω in series gives a total circuit resistance of 4000 Ω. $I_{total} = I_1 = \mathcal{E}/R_{total}$ D

31. I_1 is the main branch current and is the largest. It will split into I_2 and $I_3$and since I_2 moves through the smaller resistor, it will be larger than I_3. A

32. $P = V^2/R$ E

33. 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 B

34. 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. D

35. Summing the potential differences from left to right gives V_T = –12 V – (2 A)(2 Ω) = – 16 V. It is possible for $V_T > \mathcal{E}$. E

36. Current is greatest where resistance is least. The resistances are, in order, 1 Ω, 2 Ω, 4 Ω, 2 Ω and 6 Ω. A

37. See above E

38. Least power is for the greatest resistance ($P = \mathcal{E}^2/R$) E

39. In series, the equivalent capacitance is calculated using reciprocals, like resistors in parallel. This results in an equivalent capacitance smaller than the smallest capacitor. D

40. $V_T = \mathcal{E} - Ir$ C

41. Kirchhoff's junction rule applied at point X gives 2 A = I + 1 A, so the current in the 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 D

42.	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.	A
43.	See above	A
44.	See above	B
45.	In series $\frac{1}{C_T} = \sum \frac{1}{C}$	B
46.	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	C
47.	$P = I^2R$ and $R = \rho L/A$ giving $P \propto \rho L/d^2$	C
48.	$P = I^2R$	D
49.	Since these resistors are in series, they must have the same current.	E
50.	Each branch, with two capacitors in series, has an equivalent capacitance of 2 μF ÷ 2 = 1 μF. The three branches in parallel have an equivalent capacitance of 1 μF + 1 μF + 1 μF = 3 μF	C
51.	For each capacitor to have 6 μC, each *branch* will have 6 μC since the two capacitors in series in each branch has the same charge. The total charge for the three branches is then 18 μC. Q = CV gives 18 μC = (3 μF)V	C
52.	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	A
53.	Summing the potential differences: – 6 V – (2 A)(0.2 Ω) – (2A)(1 Ω) = – 8.4 V	C
54.	Energy = Pt = I^2Rt	C
55.	When the switch is closed, the circuit behaves as if the capacitor were just a wire, shorting out the resistor on the right.	B
56.	When the capacitor is fully charged, the branch with the capacitor is "closed" to current, effectively removing it from the circuit for current analysis.	A
57.	Total resistance = $\mathcal{E}$/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	C
58.	$P = V^2/R$ and if V is constant $P \propto 1/R$	A
59.	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)	E
60.	Kirchhoff's loop rule (V = Q/C for a capacitor)	B
61.	To dissipate 24 W means $R = V^2/P$ = 6 Ω. The resistances, in order, are: 8 Ω, 4/3 Ω, 8/3 Ω, 12 Ω and 6 Ω	E
62.	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	D
63.	The equivalent capacitance of the two 3 μF capacitors in parallel is 6 μF, combined with the 3 μF in series gives C_{total} = 2 μF	B

64. 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. D

65. 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. B

66. In series $\frac{1}{C_T} = \sum \frac{1}{C}$ E

67. $P = V^2/R$ C

68. 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. B

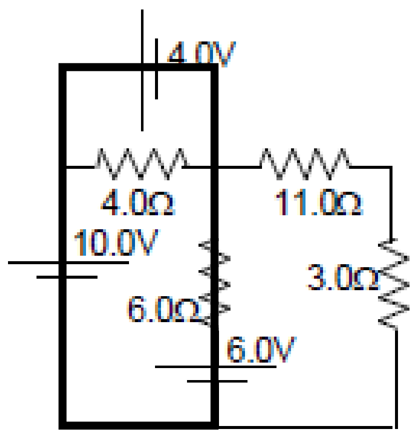
69. $R = \rho L/A \propto L/d^2$ where d is the diameter. $R_x/R_y = L_x/d_x^2 \div L_y/d_y^2 = (2L_y)d_y^2/[L_y(2d_y)^2] = ½$ B

70. 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 C

71. Summing the potential differences from bottom to top: C
left circuit: – (1 A)r + $\mathcal{E}$ = 10 V
right circuit: + (1 A)r + $\mathcal{E}$ = 20 V, solve simultaneous equations

72. 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 D

73. If you perform Kirchhoff's loop rule for the highlighted loop, you get a current of 0 A through the 6 Ω resistor. A



74. 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. D

75. See above. Current is related to brightness ($P = I^2R$) D

76. If K burns out, the circuit becomes a series circuit with the three resistors, N, M and L all in series, reducing the current through bulb N. E

77. 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. E

78. 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: $-V - (1.00\text{ mA})(25\ \Omega) + 5.00\text{ V} - (1.00\text{ mA})(975\ \Omega) = 0$ D

79. The equivalent resistance in parallel is smaller than the smallest resistance. A

80. 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. $R_{total} = 400\ \Omega$, $\mathcal{E} = 10\text{ V} = IR$ C

81. In series, they all have the same current, 2 A. $P_3 = I_3V_3$ C

82. $P = \mathcal{E}^2/R$. Total resistance of n resistors in series is nR making the power $P = \mathcal{E}^2/nR = P/n$ D

83. 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. E

84. by definition of a parallel circuit E

85. $R = \rho L/A \propto L/d^2$ where d is the diameter. $R_{II}/R_I = L_{II}/d_{II}^2 \div L_I/d_I^2 = (2L_I)d_I^2/[L_I(2d_I)^2] = ½$ C

86. $P = IV$ A

87. 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. D

88. 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 $\mathcal{E} = 8$ V. C

89. $P = V^2/R$ D

90. For the currents in the branches to be equal, each branch must have the same resistance. C

91. $R \propto L/A = L/d^2$. If $d \times 2$, $R \div 4$ and if $L \div 2$, $R \div 2$ making the net effect $R \div 8$ A

92. Bulbs in the main branch have the most current through them and are the brightest. D

93. In parallel, all the resistors have the same voltage (2 V). $P_3 = I_3V_3$ D

94. If the resistances are equal, they will all draw the same current. A

95. Resistor D is in a branch by itself while resistors A, B and C are in series, drawing less current than resistor D. D

96. 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. E

97. Each computer draws I = P/V = 4.17 A. 4 computers will draw 16.7 A, while 5 will draw over 20 A. D

98. The capacitance of the two capacitors in parallel is 2C. Combined with a capacitor in series gives $C = \frac{C \times 2C}{C + 2C} = \frac{2}{3}C$ B

99. P = IV = 1.56 kW. Energy = Pt = 1.56 kW × 8 h = 12.48 kW-h D

100. 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. $\mathcal{E} = IR$ B

101. A and E failing in the main branch would cause the entire circuit to fail. B and C would affect each other. A

102. $V = IR$ A

103. $\mathcal{E} = IR_{total}$ where $R_{total} = 35\ \Omega$ D

104. 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 $\mathcal{E} = IR$ D

105. $P = I^2R$ B

106. The equivalent resistance through path ACD is equal to the equivalent resistance through path ABD, making the current through the two branches equal E

107. 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 D

108. Since the volume of material drawn into a new shape in unchanged, when the length is doubled, the area is halved. $R = \rho L/A$ E

109. Closing the switch reduces the total resistance of the circuit, increasing the current in the main branch containing bulb 1 A

110. *Resistivity* is dependent on the material. Not to be confused with *resistance* C

111. Resistors J and N are in the main branch and therefore receive the largest current. D

112. $P = I^2R$ D

113. 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 now has a larger share of the battery voltage and the voltage across AD is the same as the voltage across BC A

114. In series circuits, larger resistors develop more power B

115. With a total resistance of 10 Ω, the total current is 1.2 A. The terminal voltage $V_T = \mathcal{E} - Ir$ C

116. Most rapid heating requires the largest power dissipation. This occurs with the resistors in parallel. E

117. $P = IV$ D

118. 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. C

119. 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 $Q_{20} + Q_5 = 4Q_5 + Q_5 = 5Q_5 = 50\ \mu C$, or $Q_5 = 10\ \mu C$ E

120. 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. $Q = It = (1.2\text{ A})(5\text{ s}) = 6\text{ C}$ E

121. For more light at a given voltage, more current is required, which requires less resistance. $R = \rho L/A$ B

122. Bulb C in the main branch receiving the total current will be the brightest C

123. Wire CD shorts out bulb #3 so it will never light. Closing the switch merely adds bulb #2 in parallel to bulb #1, which does not change the potential difference across bulb #1. C

124. 1 year = 365 days × 24 hours/day = 8760 hours. W (energy) = Pt = 0.1 kW × 8760 hours = 867 kW-h × $0.10 per kW-h = $ 86.7 — C

125. For points a and b to be at the same potential, the potential drop across the 3 Ω resistor must be equal to the potential drop across capacitor C. The potential drop across the 3 Ω resistor is three times the drop across the 1 Ω resistor. For the potential drop across capacitor C to be three times the crop across the 1 μF capacitor, C must be 1/3 the capacitance, or 1/3 μF — A

126. In parallel $\frac{1}{R_T} = \sum \frac{1}{R}$ — B

127. Shorting bulb 4 decreases the resistance in the right branch, increasing the current through bulb 3 and in the main branch containing bulb 1. — D

128. R = V/I where V = W/Q and Q = It giving R = W/I^2t and W = joules = kg m^2/s^2 — A

129. If A were to burn out, the total resistance of the parallel part of the circuit increases, causing less current from the battery and less current through bulb A. However, A and B split the voltage from the battery in a loop and with less current through bulb A, A will have a smaller share of voltage, increasing the potential difference (and the current) through bulb B. — C

130. When the current is 0.5 A, the voltage across the resistor is V = IR = 5 V. According to the loop rule, the remaining 7 V must be across the capacitor. — D

131. When the switch has been closed a long time, the voltage across the capacitor is 10 V as the current has stopped and the resistor has no potential drop across it. $U_C = ½ CV^2$ — D

132. Since there is constant current, bulb 1 remains unchanged and bulbs 2 and three must now split the current. With half the current through bulb 2, the potential difference between A and B is also halved. — D

133. The voltmeter is essentially another resistor. The voltmeter in parallel with the 100 Ω resistor acts as a 500 Ω resistor, which will half ½ the voltage of the 100 Ω resistor on the left. Thus the 120 V will split into 80 V for the 1000 Ω resistor and 40 V for the voltmeter combination. — D

134. $P = I^2R$ and the current is the same through each resistor. — A

135. The greatest current is in the main branch. — A

136. Let the current through the 1 Ω be x. The potential difference across the 1 Ω resistor is then x volts. The current will divide between the upper branch (5 Ω) and the lower branch (9 Ω) with (using the current divider ratio method) 9/(9 + 5) = 9/14 x in the upper branch and 5/14 x in the lower branch. The potential differences are then IR giving for the 2, 3, 4, 5 Ω resistors, respectively 18/14 x, 27/14 x, 20/14 x and 25/14 x volts. — C

137. The 15 Ω resistor would be in parallel with the 30 Ω resistor when the switch is closed. — C

138. ACD = 9 Ω, ABD = 9 Ω so the total resistance is 4.5 Ω making the total current $\mathcal{E}/R$ = 2 A. — A

139. The 2 A will divide equally between the two branches with 1 A going through each branch. From B to D we have – (1 A)(2 Ω) = –2 V, with B at the higher potential — A

140. When the capacitor is charged, the branch is effectively removed from the circuit, making it a simple parallel circuit. The total resistance is 133.3 Ω and V = IR — C

141. In a simple series circuit with two batteries opposing one another the voltages subtract from one another. The total effective voltage for this circuit is then 4 V. With a total resistance of 20 Ω the total current is (4 V)/(20 Ω) — E

142. For no current to flow, the potential drop across R_1 must equal the potential drop across R_2. For this to occur $I_1R_1 = I_2R_2$. Since the two branches also have the same potential difference as a whole (they are in parallel) we also have $I_1(R_1 + R_3) = I_2(R_2 + R_4)$. Solve for R_3 D

143. When the capacitor is charged, the branch is effectively removed from the circuit, making the circuit a 10 Ω resistor in series with two 10 Ω resistors in parallel. The lone 10 Ω resistor has twice the voltage of the two 10 Ω resistors in parallel with an effective resistance of 5 Ω. The 10 volts will then divide with 3.3 V going to the parallel combination and 6.7 V going to the single 10 Ω resistor. The capacitor is in parallel with the single 10 Ω resistor. Q = CV C

144. The resistances are, respectively, 4/3 R, 2/5 R, R, and 5/3 R A

145. Closing the switch adds another parallel branch, increasing the total current delivered by the battery. Bulb 3 will get brighter. Bulb 2, in its own loop with bulb 3 and the battery will then lose some of its share of the potential difference from the battery and will get dimmer. C

146. For the 3 capacitors in series on the right $C_T = C/3$. Adding to the capacitor in parallel gives C + C/3 = 4C/3 C

147. Superconductors have a property where the resistance goes to zero below a certain threshold temperature. A

148. On the right, the 6 Ω and 3 Ω resistor in parallel have an equivalent resistance of 2 Ω. Added to the 4 Ω resistance in the middle branch which is in series with the pair gives 6 Ω across the middle. This is in parallel with the 3 Ω resistor at the top giving an equivalent resistance of 2 Ω. Lastly add the 4 Ω resistor in the main branch giving a total circuit resistance of 6 Ω. V = IR. D

149. Using ratios, the currents in the 6 Ω and 3 Ω resistors are 1 A and 2 A. They have three times and 3/2 times the resistance of the 2 Ω resistor so they will have 1/3 and 2/3 the current. The total current is then 6 A giving a potential drop of 36 V across the 6 Ω resistor in the main branch and adding any one of the branches below with the loop rule gives 36 V + 6 V = 42 V for the battery B

150. Voltmeters must be placed in parallel and ammeters must be placed in series. B

151. Even though B_2 burns out, the circuit is still operating elsewhere as there are still closed paths. B

152. With B_2 burning out, the total resistance of the circuit increases as it is now a series circuit. This decreases the current in the main branch, decreasing V_1. For V_1 to be halved, the current must be halved which means the total resistance must be doubled, which by inspection did not happen in this case (total before = 5/3 R, total after = 3 R) D

153. S_1 must be closed to have any current. Closing S_2 will allow current in R_2 but closing R_3 would short circuit R_2. C

154. S_1 must be closed to have any current. Closing S_3 will short circuit R_3, leaving only resistor R_1, which is the lowest possible resistance. E

155. S_1 must be closed to have any current. The greatest voltage will occur with the greatest current through R_3 but closing S_2 or S_3 will draw current away from R_3. A

156. $R = \rho L/A$ D

157. Starting at A and summing potential differences *counterclockwise* to point C gives 12 V A

158. The branch with two 2 Ω resistors has a total resistance of 4 Ω and a potential difference of 12 V. V = IR C

159. For the 6 μF and 3 μF capacitor in series, the equivalent capacitance is 2 μF. Adding the 2 μF in parallel gives a total capacitance of 4 μF D

160. In series the capacitors have the same charge, but the smaller capacitor will have the larger potential difference (to force the same charge on a smaller area) C

161. Before cutting the resistance is R. After cutting we have two wires of resistance ½ R which in parallel is an equivalent resistance of ¼ R. $P = V^2/R$ and $I = V/R$ E

162. $P = V^2/R$ and $R = \rho L/A$ giving $P = V^2A/\rho L$ B

163. 1 kW-h = 1000 W × 60 min = 60,000 W-min = $I^2Rt = I^2(20\ \Omega)(30\text{ min})$ A