AP Physics C - Problem Drill 21: Conductors, Capacitors and Dielectrics

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question 01	**1.** Wire, X, is half as long and twice the radius of wire Y, they are made of the same material. Which wire has the higher resistance? (A) Resistance of Wire X is 8 times Wire Y. (B) Resistance of Wire X is 4 times Wire Y. (C) Resistance of Wire X is same as Wire Y. (D) Resistance of Wire X is 1/8 of Wire Y. (E) Resistance of Wire X is 1/4 of Wire Y.
Feedback on Each Answer Choice	A. Incorrect! Use the formula for resistance, $R = \rho L/A$. Resistance is proportional to the length and inversely proportional to area. Notice that the problem gives you radius not area.
	B. Incorrect! Use the formula for resistance, $R = \rho L/A$. Resistance is proportional to the length and inversely proportional to area. Notice that the problem gives you radius not area.
	C. Incorrect! Use the formula for resistance, $R = \rho L/A$. Resistance is proportional to the length and inversely proportional to area. Notice that the problem gives you radius not area.
	D. Correct! Use the formula for resistance, $R = \rho L/A$. Resistance is proportional to the length and inversely proportional to area, Area $= \pi r^2$, if the radius doubles the area will quadruple, which means the resistance goes down by a factor of four. The resistance is decreased by another factor of two because it is proportional to length.
	E. Incorrect! Use the formula for resistance, $R = \rho L/A$. Resistance is proportional to the length and inversely proportional to area. Notice that the problem gives you radius not area.
Solution	The formula for resistance of a wire is, $R = \frac{\rho L}{A}$ where ρ is the resistivity of the material, L is length and A is the area. The area of the wire, is $A = \pi r^2$. We know that radius of, X, is twice that of Y, so $r_x = 2r_y$, use the radii in the formula for area, $A_x = \pi(2r_y)^2 = 4\pi r_y^2$ and $A_y = \pi r_y^2$ We also know that the length of X is half that of Y so, $L_x = \frac{L_y}{2}$ Now use these in the formula for resistance. $R_y = \frac{\rho L_y}{\pi r_y^2}$ and $R_x = \frac{\rho L_y}{2\left(4\pi r_y^2\right)} = \left(\frac{\rho L_y}{\pi r_y^2}\right) = \frac{1}{8}R_y$ **The correct answer is (D).**

Question No. 2 of 10

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.	
Question 02	**2.** The 20 gauge wire in an electrical extension cord has a cross sectional area of 5.2×10^{-7} m^2. This wire is predominantly made of copper which has an electrical resistivity of 1.72×10^{-8} Ω•m. If your extension cord is 8.0 m long, what is the total resistance of the wire? (A) 5.3 Ω (B) 1.1×10^{-13} Ω (C) .26 Ω (D) 5.1×10^{5} Ω (E) None of the above
Feedback on Each Answer Choice	A. Incorrect! The description of 20 Gauge wire isn't used in the calculation. Sometimes additional or unnecessary information is given in a problem. Try to weed it out.
	B. Incorrect! You reversed the values for length and area in the resistance calculation.
	C. Correct! Use the formula R=ρL/A Carefully substitute values and calculate. The units end up canceling only to leave Ohms.
	D. Incorrect! Don't square the value of the area given. The unit contains meters squared, but that is the label only. There is no need to square the value itself.
	E. Incorrect! Use the formula R=ρL/A. Resistance equal resistivity times length divided by area of the wire.
Solution	**Known:** Resistivity of copper, $\rho = 1.72 \times 10^{-8}$ Ω•m Area of wire, $A = 5.2 \times 10^{-7}$ m^2 Length of wire, L = 8.0 m **Unknown:** Resistance, R =? Ω **Define:** $R = \frac{\rho L}{A}$ **Output:** Substitute carefully. No unit conversions are needed here. $R = \frac{(1.72 \times 10^{-8} \Omega \cdot m)(8.0\ m)}{(5.2 \times 10^{-7} m^2)} = .26\ \Omega$ **Substantiate**: The units cancel leaving just Ohms, the correct unit for resistance of a conductor. The relatively small value makes sense since an extension cord would be manufactured to have little resistance. **The correct answer is (C).**

Question No. 3 of 10

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.	
Question 03	**3.** How much charge can be stored on a 150 μF capacitor that is connected to a 20 V potential difference? (A) Cannot calculate, the dielectric constant for capacitor is not given. (B) 3.0×10^{-3} C (C) 3000 C (D) 7.5×10^{-6} C (E) 1.3×10^{5} C
Feedback on Each Answer Choice	A. Incorrect! The formula for capacitance contains a term for the dielectric material, but we are given the value of capacitance. You need to use a formula that relates q, C and V.
	B. Correct! Use the formula q = CV. Remember to convert from μF to F, and that 1F = 1 C/V.
	C. Incorrect! Remember to change μF to F, and that 1F = 1 C/V.
	D. Incorrect! Charge is directly proportional to voltage.
	E. Incorrect! Charge is directly proportional to capacitance.
Solution	**Known:** Voltage, V = 20V Capacitance, C = 150 μF **Unknown:** Charge stored, q =? C **Define:** Change μF to F, remember that 1F = 1 C/V Then use the formula q = CV **Output:** $150\ \mu F \times \frac{10^{-6}\ F}{1\ \mu F} = 1.50 \times 10^{-4}\ F$ $q = (1.50 \times 10^{-4}\ C/V) \times (20\ V) = 3.0 \times 10^{-3}\ C$ **Substantiate**: Units are correct, sig figs are correct, magnitude reasonable. **The correct answer is (B).**

Question No. 4 of 10

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.	
Question 04	**4.** What voltage, is required to store 7.0 x10^{-5} C of charge in a 6.0 μ F capacitor? (A) 12 V (B) 8.6x10^{5} V (C) 1.2x10^{-5} V (D) 1.2 V (E) None of the above
Feedback on Each Answer Choice	A. Correct! First change the microfarad value given into Farads. Then use the formula for the charge stored in a capacitor, q = CV, substitute values and calculate carefully.
	B. Incorrect! You reversed the values for capacitance, C, and charge, q.
	C. Incorrect! Don't' forget to change the microfarad value given into Farads.
	D. Incorrect! Use the formula for the charge stored in a capacitor, q = CV.
	E. Incorrect! Use the formula for the charge stored in a capacitor, q = CV.
Solution	**Known:** Charge, q = 7.0 x 10^{-5} C Capacitance, C = 6 μF **Unknown:** Voltage = ? V **Define:** Change μF to F, remember that 1F = 1 C/V Then use the formula q = CV Rearrange to find voltage, $V = \frac{q}{C}$ **Output:** $6.0\ \mu F \times \frac{10^{-6}\ F}{1\ \mu F} = 6.0 \times 10^{-6}\ F$ $V = \frac{(7.0 \times 10^{-5}\ C)}{(6 \times 10^{-6} C/V)} = 11.6\ V = 12\ V$ (to 2 sig fig) **Substantiate**: Units are correct, sig figs are correct, magnitude reasonable. **The correct answer is (A).**

Question No. 5 of 10

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.	
Question 05	**5.** In a parallel plate capacitor, if the size/area of each plate is doubled, and the distance between them is doubled also, how is the overall capacitance affected? (A) Doubled (B) Quadrupled (C) One half (D) One quarter (E) None of the above
Feedback on Each Answer Choice	A. Incorrect! Doubling the area of a plate will increase the capacitance, however there are other factors in this case to consider also.
	B. Incorrect! In the formula for capacitance of a parallel plate capacitor, there are no squared values.
	C. Incorrect! Consider the formula for the capacitance of a parallel plate capacitor. $C=K\varepsilon_o d/A$. Consider how the change in area and distance mentioned will affect the overall value for capacitance.
	D. Incorrect! Consider the formula for the capacitance of a parallel plate capacitor. $C=K\varepsilon_o d/A$. Consider how the change in area and distance mentioned will affect the overall value for capacitance.
	E. Correct! No overall change occurs. The area factor in the numerator and the distance factor in the denominator cancel out, so there is no net effect.
Solution	Consider the formula for the capacitance of a parallel plate capacitor. $C = \frac{K\varepsilon_0 A}{d}$ With a doubling in the area, and a doubling in the distance we get: $C = \frac{K\varepsilon_0 2A}{2d}$ The two factors of 2 cancel out. No net effect is noticed. **The correct answer is (E).**

Question No. 6 of 10

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.	
Question 06	**6.** A 10 pF capacitor is connected to a 10 V battery; the area of the capacitor is 50 cm^2. The separation of the plates is 1.0 cm, what is the dielectric constant of the material between the plates. (A) 2.3 (B) 2.3×10^{-14} (C) 23 (D) 0.23 (E) 5.6×10^{-3}
Feedback on Each Answer Choice	A. Correct! Use the formula, $C = K\varepsilon_o A/d$, rearrange to find dielectric constant k, remember to convert all units to the correct SI units.
	B. Incorrect! You used the correct formula, but did not convert the units to correct SI units.
	C. Incorrect! Use the formula $C = k\varepsilon_o A/d$, note that it does not contain any voltage terms, remember to convert to the correct SI units.
	D. Incorrect! Use the formula $C = k\varepsilon_o A/d$, note that it does not contain any voltage terms, remember to convert to the correct SI units.
	E. Incorrect! Use the formula $C = k\varepsilon_o A/d$, and rearrange to find the dielectric constant, k, pay attention to where the A and d terms are.
Solution	**Known:** Capacitance, C = 10 pF Area, A = 50 cm^2 Distance, d = 1.0 cm **Unknown**: Dielectric constant, K =? **Define:** Convert, pF to F Convert, cm to m Convert, cm^2 to m^2 Use a formula that contains, C, A, d and k. Note in this case we do not need voltage. $C = \frac{K\varepsilon_o A}{d}$ where ε_o is the permittivity of free space, $\varepsilon_o = 8.85 \times 10^{-12}$ $C^2/N \bullet m^2$ Rearrange to find K $K = \frac{Cd}{\varepsilon_o A}$ **Output:** $10.0 \text{ pF} \times \frac{10^{-12} \text{ F}}{1 \text{ pF}} = 1.0 \times 10^{-11} \text{ F}$ $1.0 \text{ cm} \times \frac{0.01 \text{ m}^2}{1 \text{ cm}^2} = 1.0 \times 10^{-2} \text{ m}$ $50 \text{ cm}^2 \times \frac{1 \times 10^{-4} \text{ m}^2}{1 \text{ cm}^2} = 5.0 \times 10^{-3} \text{ m}$ $K = \frac{(1.0 \times 10^{-11} \text{ C/V})(1.0 \times 10^{-2} \text{ m})}{(8.85 \times 10^{-12} C^2/N \bullet m^2)(5.0 \times 10^{-3} m^2)} = 2.3$ Note 1 V = 1 N•m/C **Substantiate**: There are no units for the dielectric constant, sig figs are correct, Magnitude is reasonable. **The correct answer is (A).**

Question No. 7 of 10

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.	
Question 07	**7.** How much energy can be stored in a camera flash bulb if the bulbs capacitance is 160 μF and the voltage across the bulb is 300 V? How much charge is stored on the capacitor and how much energy? (A) Charge stored = 4.8×10^{-2} C, Energy stored = 4.8×10^{-2} J (B) Charge stored = 7.8 C, Energy stored = 7.2 J (C) Charge stored = 4.8×10^{-2} C, Energy stored = 7.2 J (D) Charge stored = 5.3×10^{-7} C, Energy stored = 8.0×10^{-6} J (E) Charge stored = 4.8×10^{4} C, Energy stored = 7.2×10^{6} J
Feedback on Each Answer Choice	A. Incorrect! The energy stored is not the same as the charge stored.
	B. Incorrect! The energy stored is not the same as the charge stored.
	C. Correct! The charge stored can be found using q =CV and the energy can be found from either $U = CV^2/2$ or $U = qV/2$. Note there are a number of ways to tackle the problem, the important thing to remember is the charge and energy stored are not the same.
	D. Incorrect! The charge stored can be found using q =CV and the energy can be found from either $U = CV^2/2$ or $U = qV/2$.
	E. Incorrect! Don't forget to convert from μF to F.
Solution	**Known:** Capacitance, C = 160 μF Voltage, V = 300 V **Unknown:** Charge q = ? C Energy U_c = ? J **Define:** Note there are a number of ways to approach this problem that give the correct answer. One possible method is shown here. Change μF to F, remember that $1\text{F} = 1\text{ C/V} = 1\text{ J/V}^2$ First calculate q using q = CV Then use, Use $U_c = \frac{1}{2}CV^2 = \frac{1}{2}qV$ Note you could either use your calculated value of q or use the given value of C and V **Output:** $160\ \mu\text{F} \times \frac{10^{-6}\ \text{F}}{1\ \mu\text{F}} = 1.60 \times 10^{-4}\ \text{F}$ $q = (1.60 \times 10^{-4}\ \text{C/V}) \times (300\ \text{V}) = 4.8 \times 10^{-2}\ \text{C}$ Choose to use the given values of C and V. $U_c = \frac{1}{2}\left(1.60 \times 10^{-4}\frac{\text{J}}{\text{V}^2}\right)(300\ \text{V})^2 = 7.2\ \text{J}$ **Substantiate**: Units are correct, sig figs are correct, magnitude is reasonable. **The correct answer is (C).**

Question No. 8 of 10

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.	
Question 08	**8.** Two capacitors are identical except one is filled with a dielectric material of constant K = 3. The other one is empty between the plates. The empty one is connect to a 12.0V battery. What must the potential difference of the other battery be so that they store the same amount of energy? (A) 12 V (B) 6.9 V (C) 4.0 V (D) 16.4 V (E) 36 V
Feedback on Each Answer Choice	A. Incorrect! Don't forget about the dielectric constant, K, for one of the capacitors. This value must be factored into the capacitance when used in other formulas.
	B. Correct! Use the formula for the energy stored in a capacitor. $U_c = CV^2/2$. Set two of these terms equal to each other since the problem states they contain the same amount of energy. Be sure to add a dielectric constant of 3 for one of them. The other capacitor has a given electric potential of 12V. After cancelling, solve for the remaining voltage.
	C. Incorrect! Since the electric potential term is squared in $U_c = CV^2/2$, it is not just a linear relationship.
	D. Incorrect! Use the formula for the energy stored in a capacitor. $U_c = CV^2/2$.
	E. Incorrect! Use the formula for the energy stored in a capacitor. $U_c = CV^2/2$, notice that energy is proportional to the inverse square of voltage.
Solution	Use the formula for the energy stored in a capacitor. $U_C = \frac{1}{2}CV^2$ Since the energy stored in the two capacitors, two similar terms may be equated. $\frac{1}{2}CV^2 = \frac{1}{2}CV^2$ However, one of the capacitors has a dielectric of constant 3. Remember that capacitance is directly proportional to dielectric constant, so a factor of 3 is placed next to the capacitance for the one with the dielectric. The given voltage for the other capacitor is 12V. $\frac{1}{2}3CV^2 = \frac{1}{2}C(12V)^2$ Canceling gives a simpler equation: $3V^2 = (12V)^2$ Solve for the unknown V: $V = \sqrt{\frac{(12V)^2}{3}} = 6.9V$ **The correct answer is (B).**

Question No. 9 of 10

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.	
Question 09	**9.** What potential difference, voltage, would be needed across two plates of a 3 μF capacitor, if it was to store sufficient energy to operate a 60 W light bulb for one minute? (A) 49 V (B) 490 V (C) $6.3x10^3$ V (D) $3.5x10^4$ V (E) 4.9×10^4 V
Feedback on Each Answer Choice	A. Incorrect! Don't forget to change the microfarads into farads.
	B. Incorrect! User the formula $U_c = CV^2/2$.
	C. Incorrect! Don't forget to change the power in watts into an appropriate amount of energy in Joules for the 1 minute given.
	D. Incorrect! You forgot the factor of ½ in $U_c=CV^2/2$.
	E. Correct! Use, $U_c=1/2CV^2$, notice that the voltage is squared so remember to take the square root when you are rearrange to find V.
Solution	**Known:** Capacitance, C= 3 μF Watts = 60 W Time = 1 minute **Unknown:** Voltage =? V **Define:** Remember the definition of a Watt. 1 W= 1 J/s Convert Watts in a minute to Joules. Also, convert the microfarad capacitor into Farads. Then use: $U_C = \frac{1}{2}CV^2$ Solve for V: $V^2 = \frac{2U_c}{C}$, $V = \sqrt{\frac{2U_c}{C}}$ **Output:** $60 \frac{J}{s} \times \frac{60\ s}{1\ min} = 3600$ J in the given minute. $3\ \mu F \times \frac{10^{-6} F}{1\ \mu F} = 3 \times 10^{-6}$ F $V = \sqrt{\frac{2(3600\ J)}{3x10^{-6}\ F}} = 4.9 \times 10^4$ V **Substantiate:** Notice this is a very large value. Thus, it would take a lot, in terms of a capacitor, to store enough energy for a light bulb to run for a whole minute. The units are correct and the number of sig figs is correct. **The correct answer is (E).**

Question No. 10 of 10

Instructions: (1) Read the problem and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.	
Question 10	**10.** Calculate the field between the plates of an air filled 200 μF capacitor, if they a 2.5 mm apart and each plate holds 50 μC. (A) 250 V/m (B) 0.01 V/m (C) 100 V/m (D) 1.0×10^5 V/m (E) Insufficient information
Feedback on Each Answer Choice	A. Incorrect! The voltage across the capacitor is 250 V; you need to find an equation that links voltage, electric field and plate separation.
	B. Incorrect! Remember to convert to Farads, meters and Coulomb.
	C. Incorrect! Check that you converted to Farads, meters and Coulomb correctly.
	D. Correct! Use the formula q = CV and rearrange for V. Now use the formula that relates electric field, voltage and plate separation, E =V/d. Remember to convert all the units to the correct SI units.
	E. Incorrect! All the information needed to calculate field is given, you need to identify the relationship between, q, C and V and then the one between, E, V and d.
Solution	**Known:** Capacitance, C = 200 μF Plate separation = 2.5 mm Charge, q = 5 mC **Unknown**: Field, E =? V/m **Define:** Convert μF to F Convert mm to m Convert μC to C Use the formula q = CV and rearrange for V, $V = \frac{q}{C}$ Now use the formula that relates electric field, voltage and plate separation: $E = \frac{V}{d} = \frac{q}{Cd}$ **Output:** $200\ \mu F \times \frac{10^{-6}\ F}{1\ \mu F} = 2.00 \times 10^{-4}\ F$ $2.5\ mm \times \frac{10^{-3}\ m}{1\ mm} = 2.5 \times 10^{-3}\ m$ $50\ mC \times \frac{10^{-3}\ C}{1\ mC} = 5.0 \times 10^{-2}\ C$ $E = \frac{5.0 \times 10^{-2}\ C}{\left(2.00 \times 10^{-4} \frac{C}{V}\right)\left(2.5 \times 10^{-3}\right)} = 1.0 \times 10^5\ V/m$ **Substantiate: Units are correct, sig figs are correct, Magnitude is correct.** **The correct answer is (D).**