Chapter 19: ELECTRIC POTENTIAL AND ELECTRIC FIELD

# 19.1 ELECTRIC POTENTIAL ENERGY: POTENTIAL DIFFERENCE

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| 1. | *Find the ratio of speeds of an electron and a negative hydrogen ion (one having an extra electron) accelerated through the same voltage, assuming non-relativistic final speeds. Take the mass of the hydrogen ion to be* | |
| Solution | so that  or | |
| 2. | *An evacuated tube uses an accelerating voltage of 40 kV to accelerate electrons to hit a copper plate and produce x rays. Non-relativistically, what would be the maximum speed of these electrons?* | |
| Solution | Use energy conservation: | |
| 3. | *A bare helium nucleus has two positive charges and a mass of*  *(a) Calculate its kinetic energy in joules at 2.00% of the speed of light. (b) What is this in electron volts? (c) What voltage would be needed to obtain this energy?* | |
| Solution | (a)  (b)  (c) | |
| 4. | ***Integrated Concepts*** *Singly charged gas ions are accelerated from rest through a voltage of 13.0 V. At what temperature will the average kinetic energy of gas molecules be the same as that given these ions?* | |
| Solution | where  is the Boltzmann constant. | |
| 5. | ***Integrated Concepts*** *The temperature near the center of the Sun is thought to be 15 million degrees Celsius* *. Through what voltage must a singly charged ion be accelerated to have the same energy as the average kinetic energy of ions at this temperature?* | |
| Solution |  | |
| 6. | ***Integrated Concepts*** *(a) What is the average power output of a heart defibrillator that dissipates 400 J of energy in 10.0 ms? (b) Considering the high-power output, why doesn’t the defibrillator produce serious burns?* | |
| Solution | (a) The power is the work divided by the time, so the average power is: .  (b) A defibrillator does not cause serious burns because the skin conducts electricity well at high voltages, like those used in defibrillators. The gel used aids in the transfer of energy to the body, and the skin doesn’t absorb the energy, but rather, lets it pass through to the heart. | |
| 7. | ***Integrated Concepts*** *A lightning bolt strikes a tree, moving 20.0 C of charge through a potential difference of* *. (a) What energy was dissipated? (b) What mass of water could be raised from  to the boiling point and then boiled by this energy? (c) Discuss the damage that could be caused to the tree by the expansion of the boiling steam.* | |
| Solution | (a) Energy  (b)  (c) The expansion of the steam upon boiling can literally blow the tree apart! | |
| 8. | ***Integrated Concepts*** *A 12.0 V battery-operated bottle warmer heats 50.0 g of glass,*  *of baby formula, and*  *of aluminum from*  *to* *. (a) How much charge is moved by the battery? (b) How many electrons per second flow if it takes 5.00 min to warm the formula? (Hint: Assume that the specific heat of baby formula is about the same as the specific heat of water.)* | |
| Solution | (a) Assume that specific heat for baby formula is approximately the specific heat for water, so that    (b) Let  equal the number of electrons needed to move the charge, and  be the time necessary to move the charge. Then | |
| 9. | ***Integrated Concepts*** *A battery-operated car utilizes a 12.0 V system. Find the charge the batteries must be able to move in order to accelerate the 750 kg car from rest to 25.0 m/s, make it climb a*  *high hill, and then cause it to travel at a constant 25.0 m/s by exerting a*  *force for an hour.* | |
| Solution |  | |
| 10. | ***Integrated Concepts*** *Fusion probability is greatly enhanced when appropriate nuclei are brought close together, but mutual Coulomb repulsion must be overcome. This can be done using the kinetic energy of high-temperature gas ions or by accelerating the nuclei toward one another. (a) Calculate the potential energy of two singly charged nuclei separated by*  *by finding the voltage of one at that distance and multiplying by the charge of the other. (b) At what temperature will atoms of a gas have an average kinetic energy equal to this needed electrical potential energy?* | |
| Solution | (a)  (b) | |
| 11. | ***Unreasonable Results*** *(a) Find the voltage near a 10.0 cm diameter metal sphere that has 8.00 C of excess positive charge on it. (b) What is unreasonable about this result? (c) Which assumptions are responsible?* | |
| Solution | (a)  (b) This voltage is very high. A 10.0 cm diameter sphere could never maintain this voltage; it would discharge.  (c) An 8.00 C charge is more charge than can reasonably be accumulated on a sphere of that size. | |
| 19.2 ELECTRIC POTENTIAL IN A UNIFORM ELECTRIC FIELD | | |
| 13. | | *Show that units of V/m and N/C for electric field strength are indeed equivalent.* |
| Solution | |  |
| 14. | | *What is the strength of the electric field between two parallel conducting plates separated by 1.00 cm and having a potential difference (voltage) between them of* *?* |
| Solution | |  |
| 15. | | *The electric field strength between two parallel conducting plates separated by 4.00 cm is* *. (a) What is the potential difference between the plates? (b) The plate with the lowest potential is taken to be at zero volts. What is the potential 1.00 cm from that plate (and 3.00 cm from the other)?* |
| Solution | | (a)  (b) |
| 16. | | *How far apart are two conducting plates that have an electric field strength of*  *between them, if their potential difference is 15.0 kV?* |
| Solution | |  |
| 17. | | *(a) Will the electric field strength between two parallel conducting plates exceed the breakdown strength for air (**) if the plates are separated by 2.00 mm and a potential difference of*  *is applied? (b) How close together can the plates be with this applied voltage?* |
| Solution | | (a)  No, the field strength is smaller than the breakdown strength for air.  (b) |
| 18. | | *The voltage across a membrane forming a cell wall is 80.0 mV and the membrane is 9.00 nm thick. What is the electric field strength? (The value is surprisingly large, but correct. Membranes are discussed in Capacitors and Dielectrics and Nerve Conduction—Electrodiograms.) You may assume a uniform electric field.* |
| Solution | |  |
| 19. | | *Membrane walls of living cells have surprisingly large electric fields across them due to separation of ions. (Membranes are discussed in some detail in Nerve Conduction—Electrocardiograms.) What is the voltage across an 8.00 nm–thick membrane if the electric field strength across it is 5.50 MV/m? You may assume a uniform electric field.* |
| Solution | |  |
| 20. | | *Two parallel conducting plates are separated by 10.0 cm, and one of them is taken to be at zero volts. (a) What is the electric field strength between them, if the potential 8.00 cm from the zero volt plate (and 2.00 cm from the other) is 450 V? (b) What is the voltage between the plates?* |
| Solution | | (a)  (b) |
| 21. | | *Find the maximum potential difference between two parallel conducting plates separated by 0.500 cm of air, given the maximum sustainable electric field strength in air to be* *.* |
| S olution | |  |
| 22. | | *A doubly charged ion is accelerated to an energy of 32.0 keV by the electric field between two parallel conducting plates separated by 2.00 cm. What is the electric field strength between the plates?* |
| Solution | |  |
| 23. | | *An electron is to be accelerated in a uniform electric field having a strength of* *. (a) What energy in keV is given to the electron if it is accelerated through 0.400 m? (b) Over what distance would it have to be accelerated to increase its energy by 50.0 GeV?* |
| Solution | | (a)    (b) |
| 19.3 electric potential due to a point charge | | |
| 24. | *A 0.500 cm diameter plastic sphere, used in a static electricity demonstration, has a uniformly distributed 40.0 pC charge on its surface. What is the potential near its surface?* | |
| Solution |  | |
| 25. | *What is the potential*  *from a proton (the average distance between the proton and electron in a hydrogen atom)?* | |
| Solution |  | |
| 26. | *(a) A sphere has a surface uniformly charged with 1.00 C. At what distance from its center is the potential 5.00 MV? (b) What does your answer imply about the practical aspect of isolating such a large charge?* | |
| Solution | (a)  (b) A 1 C charge is a very large amount of charge; a sphere of 1.80 km is impractical! | |
| 27. | *How far from a*  *point charge will the potential be 100 V? At what distance will it be**?* | |
| Solution |  | |
| 28. | *What are the sign and magnitude of a point charge that produces a potential of*  *at a distance of 1.00 mm?* | |
| Solution |  | |
| 29. | *If the potential due to a point charge is*  *at a distance of 15.0 m, what are the sign and magnitude of the charge?* | |
| Solution | Since , . The charge is positive because the potential is positive. | |
| 30. | *In nuclear fission, a nucleus splits roughly in half. (a) What is the potential*  *from a fragment that has 46 protons in it? (b) What is the potential energy in MeV of a similarly charged fragment at this distance?* | |
| Solution | (a)  (b) | |
| 31. | *A research Van de Graaff generator has a 2.00-m-diameter metal sphere with a charge of 5.00 mC on it. (a) What is the potential near its surface? (b) At what distance from its center is the potential 1.00 MV? (c) An oxygen atom with three missing electrons is released near the Van de Graaff generator. What is its energy in MeV at this distance?* | |
| Solution | (a)  (b)  (c) | |
| 32. | *An electrostatic paint sprayer has a 0.200-m-diameter metal sphere at a potential of 25.0 kV that repels paint droplets onto a grounded object. (a) What charge is on the sphere? (b) What charge must a 0.100-mg drop of paint have to arrive at the object with a speed of 10.0 m/s?* | |
| Solution | (a)  (b) | |
| 33. | *In one of the classic nuclear physics experiments at the beginning of the 20th century, an alpha particle was accelerated toward a gold nucleus, and its path was substantially deflected by the Coulomb interaction. If the energy of the doubly charged alpha nucleus was 5.00 MeV, how close to the gold nucleus (79 protons) could it come before being deflected?* | |
| Solution | The alpha particle approaches the gold nucleus until its original energy is converted to potential energy. , so  (Size of a gold nucleus is about ) | |
| 34. | *(a) What is the potential between two points situated 10 cm and 20 cm from a*  *point charge? (b) To what location should the point at 20 cm be moved to increase this potential difference by a factor of two?* | |
| Solution | (a) Relative to origin, find the potential at each point and then calculate the difference.  (b) To double the potential difference, move the charge from 20 cm to . | |
| 35. | ***Unreasonable Results*** *(a) What is the final speed of an electron accelerated from rest through a voltage of 25.0 MV by a negatively charged Van de Graaff terminal? (b) What is unreasonable about this result? (c) Which assumptions are responsible?* | |
| Solution | (a)    (b) This velocity is far too great. It is faster than the speed of light.  (c) The assumption that the speed of the electron is far less than that of light and that the problem does not require a relativistic treatment produces an answer greater than the speed of light. | |
| 19.4 EQUIPOTENTIAL LINES | | |
| 36. | *(a) Sketch the equipotential lines near a point charge +**. Indicate the direction of increasing potential. (b) Do the same for a point charge* *.* | |
| Solution | (a)  (b) | |
| 37. | *Sketch the equipotential lines for the two equal positive charges shown in Figure 19.27. Indicate the direction of increasing potential.* | |
| Solution |  | |
| 38. | *Figure 19.28 shows the electric field lines near two charges  and , the first having a magnitude four times that of the second. Sketch the equipotential lines for these two charges, and indicate the direction of increasing potential.* | |
| Solution | To draw the equipotential lines, remember that they are always perpendicular to electric field lines. The potential is greatest (most positive) near the positive charge,  and least (most negative) near the negative charge,  In other words, the potential increases as you move out from the charge  and it increases as you move towards the charge | |
| 39. | *Sketch the equipotential lines a long distance from the charges shown in Figure 19.28. Indicate the direction of increasing potential.* | |
| Solution |  | |
| 40. | *Sketch the equipotential lines in the vicinity of two opposite charges, where the negative charge is three times as great in magnitude as the positive. See Figure 19.28 for a similar situation. Indicate the direction of increasing potential.* | |
| Solution |  | |
| 41. | *Sketch the equipotential lines in the vicinity of the negatively charged conductor in Figure 19.29. How will these equipotentials look a long distance from the object?* | |
| Solution | A long distance away from the conductor, the equipotential will be circles (spheres in three dimensions). | |
| 42. | *Sketch the equipotential lines surrounding the two conducting plates shown in Figure 19.30, given the top plate is positive and the bottom plate has an equal amount of negative charge. Be certain to indicate the distribution of charge on the plates. Is the field strongest where the plates are closest? Why should it be?* | |
| Solution | The field is strongest where the plates are closest, because the field is inversely proportional to the separation distance. | |
| 43. | *(a) Sketch the electric field lines in the vicinity of the charged insulator in Figure 19.31. Note its non-uniform charge distribution. (b) Sketch equipotential lines surrounding the insulator. Indicate the direction of increasing potential.* | |
| Solution | (a), (b) | |
| 44. | *The naturally occurring electric charge on the ground to an open sky point 3.00 m above is 1.13 × 102 N/C. This open point in the sky is at a greater electric potential than the ground. (a) Calculate the electric potential at this height. (b) Sketch electric field and equipotential lines for this scenario.* | |
| Solution | (a) Electric potential  . The electric field lines are perpendicular to the ground and pointing towards earth.  (b)  E  Equipotential line | |
| 45. | *The lesser electric ray (Narcine bancroftii) maintains an incredible charge on its head and a charge equal in magnitude but opposite in sign on its tail (Figure 19.32). (a) Sketch the equipotential lines surrounding the ray. (b) Sketch the equipotentials when the ray is near a ship with a conducting surface. (c) How could this charge distribution be of use to the ray?* | |
| Solution | (a) The electric field lines and equipotential lines are similar to those of the electric dipole of Figure 19.9 .  (b) Near a metal ship, the net electric field lines inside the conductor must be zero, and be perpendicular to the surface, similar to this figure:  (c) The ray uses its charge distribution to produce a large electric potential to defend itself. | |
| 19.5 CAPACITORS AND DIELECTRICS | | |
| 46. | *What charge is stored in a*  *capacitor when 120 V is applied to it?* | |
| Solution |  | |
| 47. | *Find the charge stored when 5.50 V is applied to an 8.00 pF capacitor.* | |
| Solution |  | |
| 48. | *What charge is stored in the capacitor in Example 19.8?* | |
| Solution |  | |
| 49. | *Calculate the voltage applied to a*  *capacitor when it holds*  *of charge.* | |
| Solution |  | |
| 50. | *What voltage must be applied to an 8.00 nF capacitor to store 0.160 mC of charge?* | |
| Solution |  | |
| 51. | *What capacitance is needed to store*  *of charge at a voltage of 120 V?* | |
| Solution |  | |
| 52. | *What is the capacitance of a large Van de Graaff generator’s terminal, given that it stores 8.00 mC of charge at a voltage of 12.0 MV?* | |
| Solution |  | |
| 53. | *Find the capacitance of a parallel plate capacitor having plates of area*  *that are separated by 0.100 mm of Teflon.* | |
| Solution |  | |
| 54. | *(a) What is the capacitance of a parallel plate capacitor having plates of area*  *that are separated by 0.0200 mm of neoprene rubber? (b) What charge does it hold when 9.00 V is applied to it?* | |
| Solution | (a)  (b) | |
| 55. | ***Integrated Concepts*** *A prankster applies 450 V to an*  *capacitor and then tosses it to an unsuspecting victim. The victim’s finger is burned by the discharge of the capacitor through 0.200 g of flesh. What is the temperature increase of the flesh? Is it reasonable to assume no phase change?* | |
| Solution | Let  be the specific heat of the human body (see Table 14.1)    Yes, it is reasonable to assume no phase change because the temperature is still not close to the boiling point. | |
| 56. | ***Unreasonable Results*** *(a) A certain parallel plate capacitor has plates of area 4.00 , separated by 0.0100 mm of nylon, and stores 0.170 C of charge. What is the applied voltage? (b) What is unreasonable about this result? (c) Which assumptions are responsible or inconsistent?* | |
| Solution | (a)  Now, using , it follows that    (b) The voltage is unreasonably large, more than 100 times the breakdown voltage of nylon  (c) The assumed charge is unreasonably large and cannot be stored in a capacitor of these dimensions. | |
| 19.6 CAPACITORS IN SERIeS AND PARALLEL | | |
| 57. | *Find the total capacitance of the combination of capacitors in Figure 19.33.* | |
| Solution |  | |
| 58. | *Suppose you want a capacitor bank with a total capacitance of 0.750 F and you possess numerous 1.50 mF capacitors. What is the smallest number you could hook together to achieve your goal, and how would you connect them?* | |
| Solution | You must connect the capacitors in parallel, since the total capacitance is greater than the individual capacitances.  so that | |
| 59. | *What total capacitances can you make by connecting a*  *and an*  *capacitor together?* | |
| Solution | There are two ways in which you can connect two capacitors: in parallel and in series, the total capacitance in series is:    and when connected in parallel, the total capacitance is: | |
| 60. | *Find the total capacitance of the combination of capacitors shown in Figure 19.34.* | |
| Solution |  | |
| 61. | *Find the total capacitance of the combination of capacitors shown in Figure 19.35.* | |
| Solution |  | |
| 62. | ***Unreasonable Results*** *(a) An*  *capacitor is connected in parallel to another capacitor, producing a total capacitance of* *. What is the capacitance of the second capacitor? (b) What is unreasonable about this result? (c) Which assumptions are unreasonable or inconsistent?* | |
| Solution | (a)  (b) You cannot have a negative  capacitance.  (c) The assumption that they were hooked up in parallel, rather than in series, is incorrect. A parallel connection always produces a greater capacitance, while here a smaller capacitance was assumed. This could only happen if the capacitors are connected in series. | |
| 19.7 ENERGY STORED IN CAPACITORS | | |
| 63. | *(a) What is the energy stored in the*  *capacitor of a heart defibrillator charged to* *? (b) Find the amount of stored charge.* | |
| Solution | (a)  (b) | |
| 64. | *In open heart surgery, a much smaller amount of energy will defibrillate the heart. (a) What voltage is applied to the*  *capacitor of a heart defibrillator that stores 40.0 J of energy? (b) Find the amount of stored charge.* | |
| Solution | (a)  (b) | |
| 65. | *A*  *capacitor is used in conjunction with a motor. How much energy is stored in it when 119 V is applied?* | |
| Solution |  | |
| 66. | *Suppose you have a 9.00 V battery, a*  *capacitor, and a*  *capacitor. (a) Find the charge and energy stored if the capacitors are connected to the battery in series. (b) Do the same for a parallel connection.* | |
| Solution | (a) If the capacitors are connected in series, their total capacitance is:    Then,  To determine the energy stored in the capacitors:  Note: by using the form of the equation  involving capacitance and voltage, we can avoid using one of the parameters that we calculated, minimizing our chance of propagating an error.  (b) If the capacitors are connected in parallel, their total capacitance is given by .  Again, .  And finally | |
| 67. | *A nervous physicist worries that the two metal shelves of his wood frame bookcase might obtain a high voltage if charged by static electricity, perhaps produced by friction. (a) What is the capacitance of the empty shelves if they have area*  *and are 0.200 m apart? (b) What is the voltage between them if opposite charges of magnitude 2.00 nC are placed on them? (c) To show that this voltage poses a small hazard, calculate the energy stored.* | |
| Solution | (a)  (b)  (c) | |
| 68. | *Show that for a given dielectric material the maximum energy a parallel plate capacitor can store is directly proportional to the volume of dielectric (**). Note that the applied voltage is limited by the dielectric strength.* | |
| Solution | where  is the dielectric strength, and . Thus, . Since  is the volume of dielectric, it follows that  is proportional to the volume of dielectric. | |
| 70. | ***Unreasonable Results*** *(a) On a particular day, it takes*  *of electric energy to start a truck’s engine. Calculate the capacitance of a capacitor that could store that amount of energy at 12.0 V. (b) What is unreasonable about this result? (c) Which assumptions are responsible?* | |
| Solution | (a)  (b) Such a capacitor would be too large to carry with a truck. The size of the capacitor would be enormous.  (c) It is unreasonable to assume a capacitor can store the amount of energy needed. | |

# Test Prep For AP® Courses

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| 1. | *An electron is placed in an electric field of 12.0 N/C to the right. What is the resulting force on the electron?*  (a) 1.33×10-20 N right  (b) 1.33×10-20 N left  (c) 1.92×10-18 N right (d) 1.92×10-18 N left |
| Solution | (d) |
| 2. | *A positively charged object in a certain electric field is currently being pushed west by the resulting force. How will the force change if the charge grows? What if it becomes negative?* |
| Solution | If the charge grows, the force will grow in proportion. If the charge becomes negative, the direction will change to east. |
| 3. | *A −5.0 C charge is being forced south by a 60 N force. What are the magnitude and direction of the local electric field?*  (a) 12 N/C south  (b) 12 N/C north  (c) 300 N/C south (d) 300 N/C north |
| Solution | (b) |
| 4. | *A charged object has a net force of 100 N east acting on it due to an electric field of 50 N/C pointing north. How is this possible? If not, why not?* |
| Solution | We could claim that there are other forces not listed in this problem; but with the given information, this is impossible as forces due to an electric field have to be either parallel or antiparallel with it. |
| 5. | *How many electrons have to be moved by a car battery containing 7.20×105 J at 12 V to reduce the energy by 1%?*  (a) 4.80×1027  (b) 4.00×1026  (c) 3.75×1021 (d) 3.13×1020 |
| Solution | (c) |
| 6. | *Most of the electricity in the power grid is generated by powerful turbines spinning around. Why don’t these turbines slow down from the work they do moving electrons?* |
| Solution | They would, except more energy is continually put in, generally in the form of more steam (requiring either nuclear power or fossil fuel) or water flow in the case of hydroelectricity. |
| 7. | *A typical AAA battery can move 2000 C of charge at 1.5 V. How long will this run a 50 mW LED?*  (a) 1000 minutes  (b) 120,000 seconds  (c) 15 hours (d) 250 minutes |
| Solution | (a) |
| 8. | *Find an example car (or other vehicle) battery, and compute how many of the AAA batteries in the previous problem it would take to equal the energy stored in it. Which is more compact?* |
| Solution | Using the car battery from Example 19.1, which has 7.20×105 J, compute the AAA battery as 3.0 kJ. So 240 AAA batteries have the same amount of stored potential energy. Compactness will depend on the car battery, but could go either way. |
| 9. | *What is the internal energy of a system consisting of two point charges, one 2.0 µC, and the other −3.0 µC, placed 1.2 m away from each other?*  (a) −3.8×10-2 J  (b) −4.5×10-2 J  (c) 4.5×10-2 J (d) 3.8×10-2 J |
| Solution | (b) |
| 10. | *A system of three point charges has a 1.00 µC charge at the origin, a −2.00 µC charge at x = 30 cm, and a 3.00 µC charge at x = 70 cm. What is the total stored potential energy of this configuration?* |
| Solution | −1.56×10-1 J |
| 11. | *A system has 2.00 µC charges at (50 cm, 0) and (−50 cm, 0) and a −1.00 µC charge at (0, 70 cm). As the y-coordinate of the −1.00 µC increases, the potential energy \_\_\_. As the y-coordinate of the −1.00 µC decreases, the potential energy \_\_\_.*  (a) increases, increases  (b) increases, decreases  (c) decreases, increases (d) decreases, decreases |
| Solution | (b) |
| 12. | *A system of three point charges has a 1.00 µC charge at the origin, a −2.00 µC charge at x = 30 cm, and a 3.00 µC charge at x = 70 cm. What happens to the total potential energy of this system if the −2.00 µC charge and the 3.00 µC charge trade places?* |
| Solution | It increases by 8.6×10-2 J |
| 13. | *Take a square configuration of point charges, two positive and two negative, all of the same magnitude, with like charges sharing diagonals. What will happen to the internal energy of this system if one of the negative charges becomes a positive charge of the same magnitude?*  (a) increase  (b) decrease  (c) no change (d) not enough information |
| Solution | (a) |
| 14. | *Take a square configuration of point charges, two positive and two negative, all of the same magnitude, with like charges sharing diagonals. What will happen to the internal energy of this system if the sides of the square decrease in length?* |
| Solution | The original system had net negative potential energy, due to unlike charges being closer to each other than like charges. So, with the alteration described above, the net potential energy will decrease (become more negative). |
| 15. | *A system has 2.00 µC charges at (50 cm, 0) and (−50 cm, 0) and a −1.00 µC charge at (0, 70 cm), with a velocity in the –y-direction. When the −1.00 µC charge is at (0, 0) the potential energy is at a \_\_\_ and the kinetic energy is \_\_\_.*  (a) maximum, maximum  (b) maximum, minimum  (c) minimum, maximum (d) minimum, minimum |
| Solution | (c) |
| 16. | *What is the velocity of an electron that goes through a 10 V potential after initially being at rest?* |
| Solution | 1.9×106 m/s |
| 17. | *A negatively charged massive particle is dropped from above the two plates in Figure 19.5 into the space between them. Which best describes the trajectory it takes?*  (A) A rightward-curving parabola  (B) A leftward-curving parabola  (C) A rightward-curving section of a circle  (D) A leftward-curving section of a circle |
| Solution | (b) |
| 18. | *Two massive particles with identical charge are launched into the uniform field between two plates from the same launch point with the same velocity. They both impact the positively charged plate, but the second one does so four times as far as the first. What sign is the charge? What physical difference would give them different impact points (quantify as a relative percent)? How does this compare to the gravitational projectile motion case?* |
| Solution | Negative. The second one has 100% more mass. Differences in mass have no effect on gravitational projectile motion. |
| 19. | *Two plates are lying horizontally, but stacked with one 10.0 cm above the other. If the upper plate is held at +100 V, what is the magnitude and direction of the electric field between the plates if the lower is held at +50.0 V? -50.0 V?*  (A) 500 V/m, 1500 V/m, down  (B) 500 V/m, 1500 V/m, up  (C) 1500 V/m, 500 V/m, down (D) 1500 V/m, 500 V/m, up |
| Solution | (a) |
| 20. | *Two parallel conducting plates are 15 cm apart, each with an area of 0.75 m2. The left one has a charge of -0.225 C placed on it, while the right has a charge of 0.225 C. What is the magnitude and direction of the electric field between the two?* |
| Solution | 3.4×1010 N/C to the left |
| 21. | *Consider three parallel conducting plates, with a space of 3.0 cm between them. The leftmost one is at a potential of +45 V, the middle one is held at ground, and the rightmost is at a potential of -75 V. What is the magnitude of the average electric field on an electron traveling between the plates? (Assume that the middle one has holes for the electron to go through.)*  (A) 1500 V/m  (B) 2500 V/m  (C) 4000 V/m (D) 2000 V/m |
| Solution | (d) |
| 22. | *A new kind of electron gun has a rear plate at −25.0 kV, a grounded plate 2.00 cm in front of that, and a +25.0 kV plate 4.00 cm in front of that. What is the magnitude of the average electric field?* |
| Solution | 8.33×105 V/m |
| 23. | *A certain electric potential isoline graph has isolines every 5.0 V. If six of these lines cross a 40 cm path drawn between two points of interest, what is the (magnitude of the average) electric field along this path?*  (A) 750 V/m  (B) 150 V/m  (C) 38 V/m (D) 75 V/m |
| Solution | (d) |
| 24. | *Given a system of two parallel conducting plates held at a fixed potential difference, describe what happens to the isolines of the electric potential between them as the distance between them is changed. How does this relate to the electric field strength?* |
| Solution | Assuming fixed values for the potentials that the isolines represent, these lines get closer together the closer the plates are, and spread out as the plates are moved farther apart. The closer the isolines are to each other, the greater the field strength. |
| 25. | *How would Figure 19.10 be different with two positive charges replacing the two negative charges?*  (a) The equipotential lines would have positive values.  (b) It would actually resemble Figure 19.9.  (c) no change (d) not enough information |
| Solution | (a) |
| 26. | *Consider two conducting plates, placed on adjacent sides of a square, but with a 1-m space between the corner of the square and the plate. These plates are not touching, not centered on each other, but are at right angles. Each plate is 1 m wide. If the plates are held at a fixed potential difference ΔV, draw the equipotential lines for this system.* |
| Solution | The lines need to be evenly spaced at any given point between the plates, though opening up just as the plates are. This is similar to Problem 19.42. |
| 27. | *As isolines of electric potential get closer together, the electric field gets stronger. What shape would a hill have as the isolines of gravitational potential get closer together?*  (a) constant slope  (b) steeper slope  (c) shallower slope (d) a U-shape |
| Solution | (b) |
| 28. | *Between Figure 19.9 and Figure 19.10, which more closely resembles the gravitational field between two equal masses, and why?* |
| Solution | Figure 19.10 does, because gravity is always attractive and this diagrams a same-charge situation. We also know this because, if an object is exactly centered between the two masses, this should result in no movement, which resembles Figure 19.10. Figure 19.9 is not nearly so clear. |
| 29. | *How much work is necessary to keep a positive point charge in orbit around a negative point charge?*  (a) A lot; this system is unstable.  (b) Just a little; the isolines are far enough apart that crossing them doesn’t take much work.  (c) None; we’re traveling along an isoline, which requires no work. (d) There’s not enough information to tell. |
| Solution | (c) |
| 30. | *Consider two conducting plates, placed on adjacent sides of a square, but with a 1-m space between the corner of the square and the plate. These plates are not touching, not centered on each other, but are at right angles. Each plate is 1 m wide. If the plates are held at a fixed potential difference ΔV, sketch the path of both a positively charged object placed between the near ends, and a negatively charged object placed near the open ends.* |
| Solution | The negatively charged object will go toward the higher potential plate, the positively charged toward the lower potential plate, both describing arcs that are sections of circles. |
| 31. | *Two parallel plate capacitors are otherwise identical, except the second one has twice the distance between the plates of the first. If placed in otherwise identical circuits, how much charge will the second plate have on it compared to the first?*  (a) four times as much  (b) twice as much  (c) the same (d) half as much |
| Solution | (d) |
| 32. | *In a very simple circuit consisting of a battery and a capacitor with an adjustable distance between the plates, how does the voltage vary as the distance is altered?* |
| Solution | It doesn’t. The capacitance and charge will vary, but the voltage will remain a constant, so long as the battery retains internal energy. |
| 33. | *A parallel plate capacitor with adjustable-size square plates is placed in a circuit. How does the charge on the capacitor change as the length of the sides of the plates are increased?*  (a) it grows proportional to length2  (b) it grows proportional to length  (c) it shrinks proportional to length (d) it shrinks proportional to length2 |
| Solution | (a) |
| 34. | *Design an experiment to test the relative permittivities of various materials, and briefly describe some basic features of the results.* |
| Solution | Have a parallel plate capacitor with a fixed, equal amount of charge on each plate, and a fixed distance between the plates. Then put in different materials cut in identical shapes to fit between the plates, and measure the drop in voltage. Then use *V* = *Ed* and *κ* = *E*0/*E* to calculate the relative permittivities. Note that they should all be greater than one. |
| 35. | *A student was changing one of the dimensions of a square parallel plate capacitor and measuring the resultant charge in a circuit with a battery. However, the student forgot which dimension was being varied, and didn’t write it or any units down. Given the table, which dimension was it?*  [Table 19\_05\_01]   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Dimension | 1.00 | 1.10 | 1.20 | 1.30 | | Charge(µC) | 0.50 | 0.61 | 0.71 | 0.86 |   (a) The distance between the plates  (b) The area  (c) The length of a side (d) Both the area and the length of a side |
| Solution | (c) |
| 36. | *In an experiment in which a circular parallel plate capacitor in a circuit with a battery has the radius and plate separation grow at the same relative rate, what will happen to the total charge on the capacitor?* |
| Solution | In the experiment, having a battery means that the voltage is constant, so the charge and capacitance are exactly proportional. The area and capacitance increase as the square of the radius. The capacitance decreases with the distance. So the capacitance (and hence charge) will go up linearly with the increase in dimensions. |
| 37. | *Consider a parallel plate capacitor, with no dielectric material, attached to a battery with a fixed voltage. What happens when a dielectric is inserted into the capacitor?*  (a) Nothing changes, except now there is a dielectric in the capacitor.  (b) The energy in the system decreases, making it very easy to move the dielectric in.  (c) You have to do work to move the dielectric, increasing the energy in the system. (d) The reversed polarity destroys the battery. |
| Solution | (c) |
| 38. | *Consider a parallel plate capacitor with no dielectric material. It was attached to a battery with a fixed voltage to charge up, but now the battery has been disconnected. What happens to the energy of the system and the dielectric material when a dielectric is inserted into the capacitor?* |
| Solution | We increase the capacitance. However, the charge is now fixed. This means that the voltage and energy both decrease. The capacitor actually does work on the dielectric, pulling it in. |
| 39. | *What happens to the energy stored in a circuit as you increase the number of capacitors connected in parallel? Series?*  (a) increases, increases  (b) increases, decreases  (c) decreases, increases (d) decreases, decreases |
| Solution | (b) |
| 40. | *What would the capacitance of a capacitor with the same total internal energy as the car battery in Example 19.1 have to be? Can you explain why we use batteries instead of capacitors for this application?* |
| Solution | 104 Farads, which is an enormous capacitance, probably beyond our capability to manufacture in that size. |
| 41. | *Consider a parallel plate capacitor with metal plates, each of square shape of 1.00 m on a side, separated by 1.00 mm. What is the energy of this capacitor with 3.00×103 V applied to it?*  (a) 3.98×10-2 J  (b) 5.08×1014 J  (c) 1.33×10-5 J (d) 1.69×1011 J |
| Solution | (a) |
| 42. | *Consider a parallel plate capacitor with metal plates, each of square shape of 1.00 m on a side, separated by 1.00 mm. What is the internal energy stored in this system if the charge on the capacitor is 30.0 µC?* |
| Solution | 5.08×10-2 J |
| 43. | *Consider a parallel plate capacitor with metal plates, each of square shape of 1.00 m on a side, separated by 1.00 mm. If the plates grow in area while the voltage is held fixed, the capacitance \_\_\_ and the stored energy \_\_\_.*  (a) decreases, decreases  (b) decreases, increases  (c) increases, decreases (d) increases, increases |
| Solution | (d) |
| 44. | *Consider a parallel plate capacitor with metal plates, each of square shape of 1.00 m on a side, separated by 1.00 mm. What happens to the energy of this system if the area of the plates increases while the charge remains fixed?* |
| Solution | The capacitance increases, but because the charge is fixed, the internal energy drops. |

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