Exam II: Chapters 15—17

1. According to the principle of charge quantization,
    A) an object might carry -1.6×10^{-19}C of excess charge, but never $+1.6 \times 10^{-19}$C of excess charge.
    B) **an object might carry $\pm n(1.6 \times 10^{-19})$C of excess charge, where n must be an integer value.**
    C) an object might carry $\pm n(1.6 \times 10^{-19})$C of excess charge, where n may be any real number.
    D) every proton carries an identical charge, but the charge on an electron may vary.
    E) every electron must have the same charge as every proton: q = $+1.6 \times 10^{-19}$C.

2. According to the principle of charge conservation,
    A) charges must always exist in pairs of one negative and one positive charge.
    B) removing a charge (electron or proton) from an atom instantly causes the creation of a new equivalent charge to replace it.
    C) every electron must have the same charge as every proton: q = $+1.6 \times 10^{-19}$C.
    D) **charge cannot be created or destroyed. Charges can be moved or transferred between objects, but with no net change in the overall quantity of charge.**
    E) when a proton and electron come together, they will annihilate because the net charge will be zero.

3. By scuffling across the carpet, you accumulate an excess charge of -2.0×10^{-19}C.
    A) This is a dangerous amount of charge. You will be electrocuted when you touch the light switch.
    B) This is pretty substantial, but not lethal. Don't touch the kitty's nose, that's just mean.
    C) This is a very small amount of charge. If you touched the light switch, you might feel a very small shock.
    D) This is a trick question. You cannot accumulate an excess negative charge.
    E) **This is a trick question. You *can* accumulate a negative charge, just not *this* particular quantity of negative charge.**

4. If you charge a plastic rod or comb by rubbing it with a wool cloth, you are
    A) experiencing a hallucination. Charges cannot be moved; that is the fundamental principle of charge conservation!!
    B) using conduction to move negative charges from the rod to the cloth.
    C) using induction to move positive charges from the cloth to the rod.
    D) **using friction to move negative charges from the cloth to the rod.**
    E) using pair production to create new proton-antiproton pairs. The protons stay on the cloth (positive) and the anti-protons move to the rod, making it negative.

5. How did you get that aluminum sphere to be positively charged?
    A) Easy. First I pulled some protons off the nuclei of the carbon atoms in my graphite rod. Then I touched the positively charged rod to the metal sphere. Next question?
    B) I connected the electrically neutral sphere to the ground with a copper wire. Because copper is a conductor, electrons from the sphere naturally want to travel to ground.
    C) Just connecting a ground wire is insufficient. You also need a second wire, attached to a voltage source. Power up the source, and the sphere charges automatically.
    D) **First I polarized the sphere by holding a negatively charged rod close (but not touching) to the left side. When negative charges are repelled to the right, I attached a grounding wire to conduct them away from the sphere.**
    E) None of these answers will result in a positively charged sphere. The (+) on the sphere are just the sign convention leftover from the 1800s, before anyone knew that electrons existed and were negatively charged.

6. You approach the electroscope bulb with a negatively charged rod, but do not touch the rod to the bulb.
    A) I would not do that if I were you. This is incredibly dangerous, and you could get electrocuted.
    B) The foil leaves separate, because one leaf is positive and the other will be negative. One leaf becomes negative when the rod attracts positive charges to the bulb.
    C) It's hard to see, but the leaves will actually draw closer together. The negative rod pulls protons to the bulb, causing the negative foil leaves to be pulled together as well.
    D) The foil leaves of the electroscope will separate. Negative charges from the rod will be conducted to the bulb, and move to the foil, where the leaves repel each other.
    E) **The leaves separate because the negatively charged rod repels the electrons in the bulb. The negative charges try to move as far away from each other as they can, which separates the foil leaves. The net charge on the electroscope, however, remains zero.**

7. Charge q_1 =+3.0μC is positioned at the origin (0, 0). Charge q_2 = +6.0μC is fixed at (0.30m, 0.40m). What is the **direction** of the force on q_2 because of q_1?
    A) The force has only a +x component.
    B) The force has only a +y component.
    C) **The force has +x and +y components.**
    D) The force has +x and –y components.
    E) The force has -x and –y components.
    F) The force has -x and +y components.

8. To **increase** the magnitude of the force by a factor of 2, move charge q_2 to
    A) (0.075m, 0.10m).
    B) (0.15m, 0.20m).
    C) **(0.21m, 0.28m)**
    D) (0.42m, 0.57m).
    E) (0.60m, 0.80m).
    F) (1.2m, 1.6m).
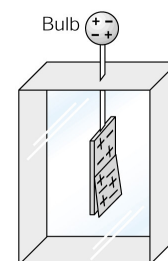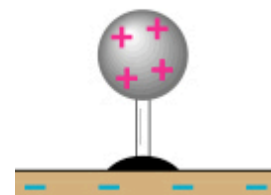
9. Assume that the two charges are in their initial locations. Charge q_2 is replaced with **+2.0μC**. The force on q_1
    A)   decreases to 1/9 its previous magnitude.   C)   triples.
    B)   **decreases to 1/3 its previous magnitude.**   D)   increases by a factor of 9.

10. Two charges have opposite sign, but the same magnitude q. How much **work** must be done by an **external force** to
    bring the charges together from ∞ to a separation r?
    A) $U = +(kq^2)/r$ C) $U = +(kq)/r^2$ E) $U = 0$
    B)   **$U = -(kq^2)/r$**   D) $U = -(kq)/r^2$

11. What is most responsible for making insulators poor conductors of charge?
    A)   **A full valence shell makes it difficult to move electrons from atom to atom.**
    B)   The high density of most insulators effectively prevents the movement of any charges.
    C)   They have a crystal structure; the long-range order makes it difficult to move electrons.
    D)   They typically have heavy nuclei: the more protons in the nucleus, the more difficult it becomes to pull protons
         out of the nucleus and pass them from atom to atom.
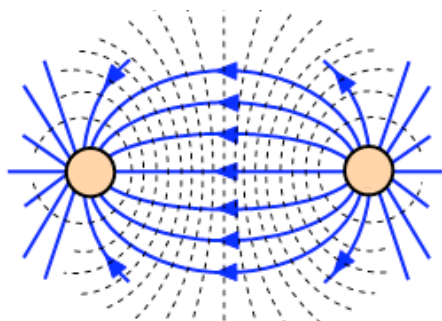
Two point charges are placed as shown to the left. Answer the following
questions **12 through 16** using the responses:
T = TRUE   F = FALSE   E = UNKNOWN

12. **True** or false: The left point is negative and the right point is positively
    charged.

13. True or **false**: There is not enough information on this diagram to
    uniquely determine the sign of either charge.

14. True or **false**: The field strength is zero at the point exactly halfway
    between the charges.

15. **True** or false: The solid lines indicate the path that a positive charge
    would follow if it was released at some point on a specific line.

16. True or **false**: A negative charge placed exactly half way between the point charges will be in equilibrium: it will not
    move in any direction.

17. A positive charge (+q) is positioned at the origin, and a second positive charge (+3q) is fixed at (0.10m, 0). Where
    would you place a positive test charge in order that it feels zero force (it is in equilibrium)? Assume +x = → and +y = ↑.
    A)   Nowhere; there is no equilibrium position for a positive test charge.
    B)   On the x-axis, to the right of (+q): x > 0.10m.
    C)   On the x-axis, to the left of (+3q): x < 0.
    D)   On the x-axis, exactly in between the charges: (0.05m, 0).
    E)   **Somewhere on the x-axis, between 0 and 0.10m. Closer to (+q) than (+3q).**

18. The positive and negative charges shown have the same
    magnitude. A positive test charge placed at point P will
    experience a net force **F** (assume +x = → and +y = ↑)
    A)   in the +x direction.
    B)   in the −x direction.
    C)   in the +y direction.
    D)   **in the −y direction.**
    E)   with components in the +x and −y directions.

19. What is the direction of the electric field vector **E** at point P?
    A)   **E points in the same direction (parallel) as the net force F.**
    B)   **E** points in the opposite direction (parallel but negative) as the net force **F**.
    C)   **E** points in the direction perpendicular to the net force **F**.
    D)   **E** =0. There is no field, so there is no direction.
    E)   **E** has components in both the +x and +y directions, but they are unrelated to the components of the force vector.
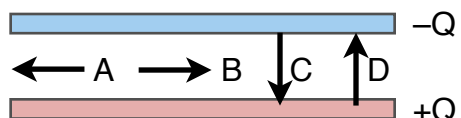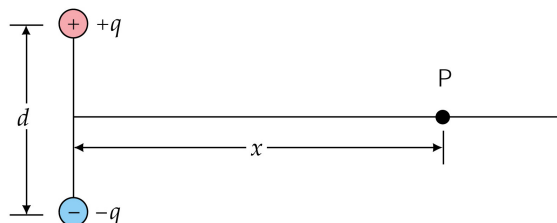
Two conducting plates are arranged parallel to each other as shown. The
plates are charged as labeled. **Q=3.5μC** and the plates have an area **A =
0.07m²**.

20. The electric field vector is shown by which arrow? **D**

21. Calculate the electric field strength. Express your answer in megaN/C
   (10^6N/C), and use two sig figs.

$$E = \frac{4\pi kQ}{A} = \frac{4\pi\left(9\times10^9\ \frac{\text{N·m}^2}{\text{C}^2}\right)\left(3.5\times10^{-6}\text{C}\right)}{\left(0.07\text{m}^2\right)} = 5.65\times10^6\ \frac{\text{N}}{\text{C}}$$

22. Decreasing the plate separation will
    A) **have no effect on the magnitude of the field.**
    B) change the direction of the field from A to B.
    C) change the direction of the field from D to C
    D) increase the magnitude of the electric field.
    E) decrease the magnitude of the electric field.

23. To double the electric field between the two plates, you should
    A) double the quantity of charge, from Q to 2Q.
    B) halve the quantity of charge, from Q to ½Q.
    C) double the plate area from A to 2A.
    D) halve the plate area from A to ½A.
    E) **do either A or D, but not both.**
    F) do both B and C, but not separately.

24. On the figure on the right, two opposite point charges +Q and −Q are separated by a fixed distance d. The equipotentials
    A) are represented by the solid lines.
    B) **are represented by the dotted lines.**
    C) are single points located exactly where the point charges are located.
    D) are represented by the empty spaces between both sets of lines.
    E) are non-existent. There are no equipotentials possible for the configuration of charge shown.
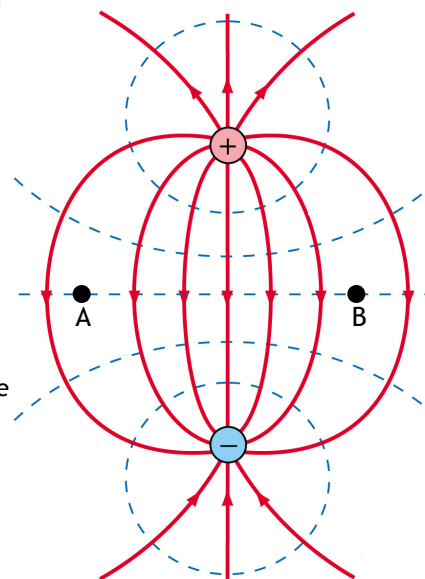
25. A positive test charge +q is placed at point A. How much work will be done to move the charge along the dotted line, from point A to point B?
    A) **None.**
    B) W = qV, so multiply the charge q by the voltage of the equipotential.
    C) W = Ed, so multiply the magnitude of the electric field by the distance d between the fixed charges +Q and −Q.
    D) W = (F_x)x, so multiply the x-component of the force on the test q due to the fixed charges by the distance x from A to B.
    E) There's no way to calculate this, because to be complete, you would have to include the work done by both the electric field and the gravitational field—and we have no idea what the gravitational field looks like (whether the path is a vertical circle or a horizontal circle!
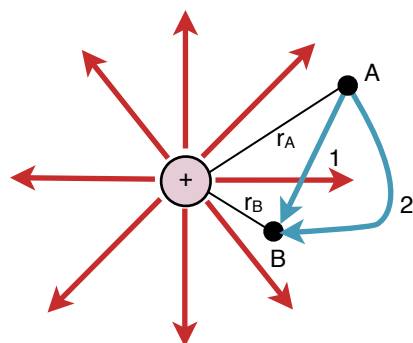
A point charge +Q is fixed as shown on the left.

26. True or **false**: More work must be done on a test charge to move it from A to B along path 2, and less work done along path 1.

27. **True** or false: The potential is smaller at point A than at point B.

28. **True** or false: The potential difference ΔV from A to B is positive.

29. A positive charge has a magnitude of **+4.25µC**. Determine the radius of the 0.5kV (**500V**) equipotential. Express your answer in meters (two sig figs).

$$V = \frac{kQ}{r} \Rightarrow r = \frac{kQ}{V} = \frac{\left(9 \times 10^9 \; \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}\right)\left(4.25 \times 10^{-6}\text{C}\right)}{500\text{V}} = 76.5\text{m}$$

30. What does it mean to say "electrons fall up?"
    A) Electrons are not subject to gravitational forces.
    B) An electron will fall away from a positive charge, from higher potential to lower potential.
    C) **An electron will fall away from another negative charge, from lower potential to higher potential.**
    D) An electron will fall toward another negative charge, from a higher potential to a lower potential.
    E) Nothing, really. It's a cliché, like saying "It's raining cats and dogs!" Nobody really thinks that several species of small furry animals are falling out of the sky.

The parallel plate capacitor shown in the circuit on the right has an area **0.15m²**, a plate separation of **0.4mm**, and is attached to a **9V** battery.

31. How much **work** is done to move a **+3.0µC** charge from the positive to the negative plate? Express your answer in **µJ** (10⁻⁶J), with two sig figs.

$$\Delta V = \frac{W}{q} \Rightarrow W = qV = \left(3.0\mu\text{C}\right)\left(9\text{V}\right) = 27\mu\text{J}$$

32. What is the **capacitance**? Answer in **nanoFarads** (10⁻⁹F) with two sig figs.

$$C = \frac{\varepsilon_o A}{d} = \frac{\left(8.85 \times 10^{-12} \; \frac{\text{C}}{\text{N} \cdot \text{m}}\right)\left(0.15\text{m}^2\right)}{\left(0.4 \times 10^{-3}\text{m}\right)} = 3.32 \times 10^{-9}\text{F}$$
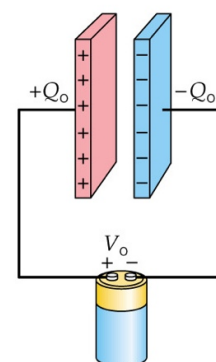
33. If the 6V battery is replaced by a 12V battery, the amount of stored charge
    A) remains constant, and the capacitance increases.
    B) decreases while the capacitance remains constant.
    C) decreases while the capacitance increases.
    D) increases while the capacitance remains constant.
    E) increases while the capacitance increases as well.

34. How does the replacing the battery change the amount of energy stored?
    A) It doesn't; $U = \frac{1}{2}Q^2/C$, so the energy remains constant.
    B) Since $U = \frac{1}{2}QV$, doubling the voltage doubles the stored energy.
    C) Because $U = \frac{1}{2}CV^2$, doubling the voltage quadruples the stored energy.
    D) $U = mgh$, but the charges are not subject to gravity. No gravity, no energy. The battery is not relevant.

35. We know that inserting a dielectric between the plates of a capacitor will *increase* the capacitance ($C = \kappa C_o$). How, then, can inserting a dielectric actually *decrease* the amount of energy stored by the capacitor?
    A) Capacitance and energy will both be *increased* by the dielectric. There is no way to *decrease* the energy.
    B) Neither the capacitance nor the energy will change as a result of the dielectric. $C = \kappa C_o$ is not a correct equation.
    C) If you leave the battery connected while you insert the dielectric, the capacitance increases but energy decreases.
    D) Disconnecting the battery before inserting the dielectric means that some of the stored energy will be used to do work to pull the dielectric material in. This leaves less energy in the capacitor.
    E) Battery connected or not does not matter. The dielectric reduces the amount of charge stored, reducing the energy stored as well.
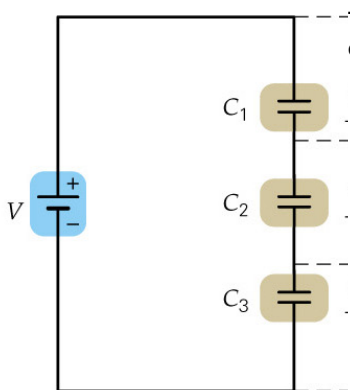
The circuit on the left has a **12V** battery connected to three capacitors in series. The capacitances are $C_1 = 2\mu F$, $C_2 = 4\mu F$, and $C_3 = 5\mu F$.

36. Which individual capacitor stores the greatest amount of **charge**?
    A) Capacitor 1.
    B) Capacitor 2.
    C) Capacitor 3.
    D) Trick question. There is no charge stored on any of the capacitors.
    E) Trick question. The charge is identical on each of the capacitors.

37. The **voltage** is greatest across which capacitor?
    A) Capacitor 1.
    B) Capacitor 2.
    C) Capacitor 3.
    D) Trick question. There is no voltage across any of the capacitors.
    E) Trick question. The voltage is identical across each of the capacitors.

38. The same three capacitors are rewired so that they are now in **parallel** with the original **12V** battery. Compare the amount of **energy** stored by each capacitor.
    A) Each capacitor stores less charge, so the parallel capacitors store less energy than the series capacitors.
    B) Each capacitor stores *more* charge, so the parallel capacitors store *more* energy than the series capacitors.
    C) The battery is the same. The capacitors are the same. The amount of energy stored is the same either way.

39. Are the batteries in your flashlight in series or parallel?
    A) Series.   B) Parallel.   C) Neither.

40. When the switch is closed on the circuit shown on the right, what is the direction of the current?
    A) There will be no current unless the switch is left open!
    B) Electrons will move clockwise, so the current will be counterclockwise.
    C) Electrons will move clockwise, so the direction of the current is clockwise.
    D) Electrons move counterclockwise, so that is the direction of the current.
    E) Electrons move counterclockwise, so the direction of current is clockwise.

41. When the switch is closed on the circuit, the ammeter (device R) reads 0.5A.
    A) Electrons are pushed away from the negative terminal of the power supply, and travel all the way around the circuit until they reach the positive terminal of the power supply.
    B) Electrons are sort of moving. If the current is 1A, this would mean 1 electron was moving around the circuit; 0.5A is impossible because it would mean only half an electron moved!
    C) Electrons are not moving at all. The definition of current says that (+) charges are moving. If the ammeter reads 0.5A, it's because *protons* are moving around the circuit from (+) to (-).
    D) Electrons and protons are both moving, and in opposite directions. There will be 0.25A of electrons moving (+) to (-) around the circuit, and 0.25A of protons moving in the opposite direction, (-) to (+).
    E) Electrons are moving, but not all the way around the circuit. They move locally, and if the electrons are moving to the left, the convention says that current flows to the right.
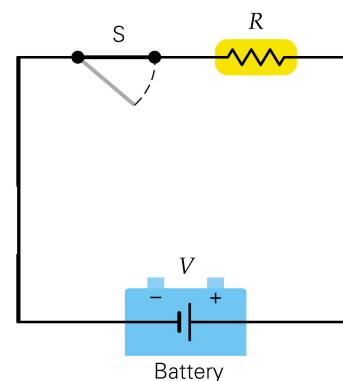
42. Two wires are made of the same copper. Different lengths, different thicknesses.
    A)   The wires will have the same resistance, because they are made of the same material.
    B)   The longer wire will have less resistance then the shorter wire.
    C)   The thicker wire will have less resistance than the thinner wire.
    D)   The wire with the thicker coating of insulation will have greater resistance regardless of the material or geometry of the wire.

43. Two wires have the same length and the same diameter. One is copper (ρ_{Cu} = 1.70x10^{-8}Ω·m), the other is NiChrome (ρ_{NiCr} = 100x10^{-8}Ω·m). At room temperature (20°C), the copper wire
    A)   will have greater resistance than the NiChrome.
    B)   will have exactly the same resistance as the NiChrome wire.
    C)   will have a smaller resistance than the NiChrome wire.
    D)   cannot be compared to the NiChrome; there is no way to determine which wire will have greater resistance.

44. What is the **resistance** of an electric coffee grinder that draws a current of **5A** when connected to a **110-V** household circuit? Answer to the nearest integer.

$$V = IR \Rightarrow R = \frac{V}{I} = \frac{110\text{V}}{5\text{A}} = 22\Omega$$

45. How much **power** does this coffee grinder use? Answer to the nearest integer.

$$P = IV = (5\text{A})(110\text{V}) = 550\text{W}$$