Exam II: Chapters 15—17
Solution

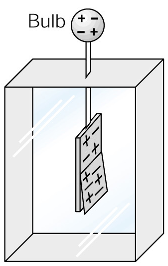
1. Compare the charge of an electron with the charge on a proton.
   A) They are the same: same magnitude, same sign.
   B) Why? Neither an electron nor a proton carry charge. Neutrons carry negative charge.
   C) **The charges have the same magnitude, but they are opposite sign. Electrons are negative.**
   D) A proton, because it is about 10,000 times more massive, carries about 10,000 times more charge.
   E) Electrons are tiny but mighty: they are less massive, but carry 10,000 times more charge than protons.

2. Explain the concept of charge quantization.
   A) Charges must always exist in pairs of one positive and one negative charge.
   B) Charges can be created or destroyed, but cannot be transferred among objects.
   C) Charges can be moved around, but only inside the actual atom where they exist.
   D) **Charges can only exist as whole numbers of particles: you cannot have half an electron.**
   E) Charges can be moved or transferred from one object to another, but not created or destroyed.

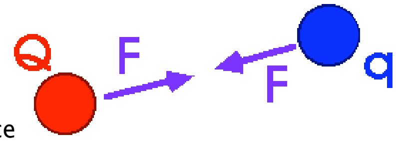
3. Explain the concept of charge conservation.
   A) Charges must always exist in pairs of one positive and one negative charge.
   B) Charges can be created or destroyed, but cannot be transferred among objects.
   C) Charges can be moved around, but only inside the actual atom where they exist.
   D) Charges can only exist as whole numbers of particles: you cannot have half an electron.
   E) **Charges can be moved or transferred from one object to another, but not created or destroyed.**

4. If you charge a plastic rod or comb by rubbing it with a wool cloth, you are
   A) conducting negative charges from the rod to the cloth.
   B) using induction to move positive charges from the cloth to the rod.
   C) **using friction to move negative charges from the cloth to the rod.**
   D) 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.
   E) experiencing a hallucination, because charges cannot be moved. That is the fundamental principle of charge conservation!!

5. You move the charged rod close to a stream of water from the faucet.
   A) Why? Nothing happens because water is not a metallic conductor.
   B) I would not do that if I were you. This is incredibly dangerous, and you could get electrocuted.
   C) **The stream of water is deflected as the polar molecules are pulled or pushed by the charged rod.**
   D) The stream of water is deflected as the negatively charged rod pulls the hydrogen nuclei (protons) right out of the molecules. The hydrogen gas escapes while the stream is pushed away from the rod.
   E) Sometimes this works, sometimes not. It's a parlor trick that has nothing to do with electric charges. Whether or not the stream deflects is a function of the strength of the magnetic field of the rod (so your rod needs an iron core to be magnetic).



6. Bring a negatively charged rod close to the bulb of the electroscope shown on the right.
   A) Nothing happens. Nothing can happen unless you touch the rod to the bulb.
   B) I would not do that if I were you. This is incredibly dangerous, and you could get electrocuted.
   C) The foil leaves separate, but it is because one leaf is positive and the other will be negative. One leaf becomes negative when the rod attracts positive charges to the bulb.
   D) 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.
   E) **The foil leaves of the electroscope will separate. Negative charges from the bulb will be repelled from the rod, and move to the foil, where the leaves repel each other.**

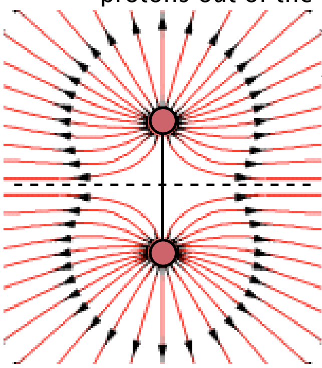


7. What can you say with certainty about the charge q shown on the right?
   A) Charge q must have the same magnitude and same sign as charge Q.
   B) Charge q must have the same magnitude, but opposite sign as Q.
   C) Charge q must have the same magnitude as charge Q because the force arrows on each charge are the same length. The sign of q cannot be determined with respect to charge Q.
   D) **Charge q must have the opposite sign as Q, but you cannot tell anything about the relative magnitudes of the charges.**
   E) There is no way to conclude anything at all about either the sign or the magnitude of charge q compared to charge Q.

8. If you move charge q to a new position twice as far from Q, the force between the charges
   - A) doubles.
   - B) quadruples.
   - C) does not change.
   - D) decreases to ½ its previous magnitude.
   - **E) decreases to ¼ its previous magnitude.**

9. Assume that charges q and Q are equal in magnitude. Without changing the separation, you replace q with a new charge twice as big. The force between the charges
   - **A) doubles.**
   - B) quadruples.
   - C) does not change.
   - D) decreases to ½ its previous magnitude.
   - E) decreases to ¼ its previous magnitude.

10. 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 charges are separated by a distance r. Shown left is the electric field that results. Answer the following questions A for **true**, and B for **false**.

11. The charges have the same magnitude.

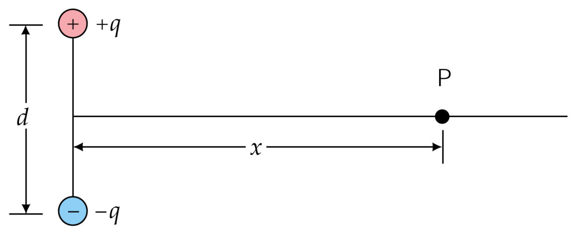
12. Both charges shown are negative.

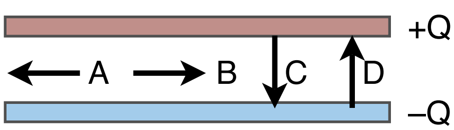
13. The field strength is maximum at the midpoint of a line connecting the two charges.

14. The field strength is non-zero along the dotted line shown.

15. The field strength decreases as the distance increases.

16. The positive and negative charges shown have the same magnitude. What is the direction of the electric field **E** at point P? Assume +x = → and +y = ↑.
    - A) **E** points in the +x direction.
    - B) **E** points in the -x direction.
    - C) **E** points in the +y direction.
    - **D) E points in the -y direction.**
    - E) **E** has components in both the +x and +y directions.





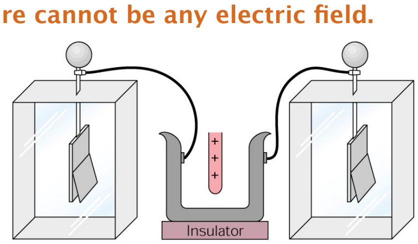
Two conducting plates are arranged parallel to each other as shown. The plates are charged as labeled.

17. The electric field vector is shown by which arrow? **C**

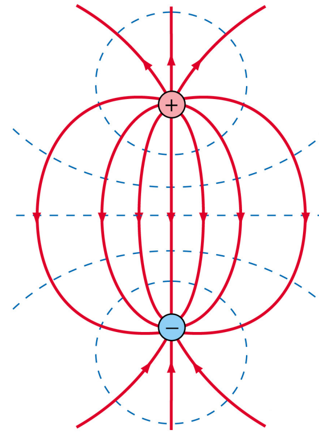
18. Increasing the plate separation will
    - A) have no effect on the magnitude of the field.
    - B) change the direction of the field from A to B.
    - C) change the direction of the field from D to C.
    - D) increase the magnitude of the electric field.
    - **E) decrease the magnitude of the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

19. The electric field inside a charged conducting sphere
    - A) depends on the radius of the sphere: the larger the sphere, the smaller the electric field.
    - B) depends on the radius, but it is a direct proportionality: bigger radius, bigger electric field.
    - C) is independent of the radius. It is constant, and depends only on the amount of charge on the sphere.
    - D) is inversely proportional to the amount of charge on the sphere, and directly proportional to the radius.
    - **E) is zero. It has to be; there is no net force inside the sphere, so there cannot be any electric field.**

20. An isolated metal container has uncharged electroscopes conductively attached to its inside and outside surfaces. When the positively charged rod is held inside the container as shown,
    - A) neither electroscope shows any deflection of the leaves.
    - B) only the electroscope attached to the inner surface deflects.
    - C) only the electroscope attached to the outer surface deflects.
    - **D) both electroscopes deflect by the same amount.**

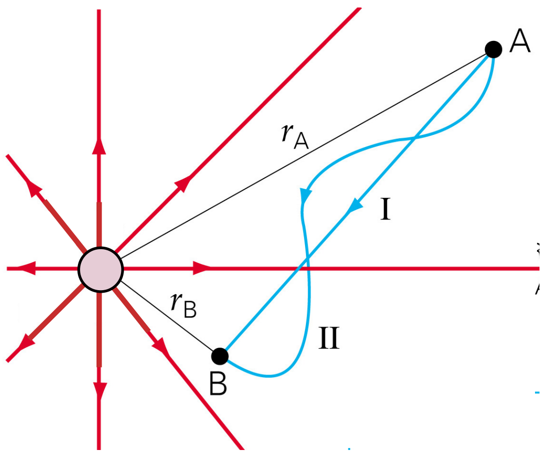


21. Compare the force of gravity on an object to an electrostatic force on an object.
   A) Why? There is no basis for comparison because the forces exist for entirely different reasons, and behave entirely differently.
   B) The forces exist for the same reason, because all atomic particles have electric charge. However, the forces do not behave the same.
   C) Both are action-at-a-distance forces which follow the same mathematical pattern: the inverse-square law. The difference is that gravity is conservative, but electrostatic forces are non-conservative.
   D) Answer C is correct, all the way up to the bit about the electrostatic force being non-conservative. Both forces are examples of conservative forces.
   E) Both forces are non-conservative. Although they appear to have similar behavior, when described mathematically, it becomes apparent that they do not really behave similarly at all.



22. On the figure on the right, 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.

23. Which is the 0-volt equipotential?
   A) The vertical solid line connecting the two charges.
   B) The curved solid line that makes the largest circle with the charges at top and bottom.
   C) The dotted line that encircles the top charge.
   D) The dotted line that encircles the bottom charge.
   E) The straight, horizontal dotted line between the two charges.



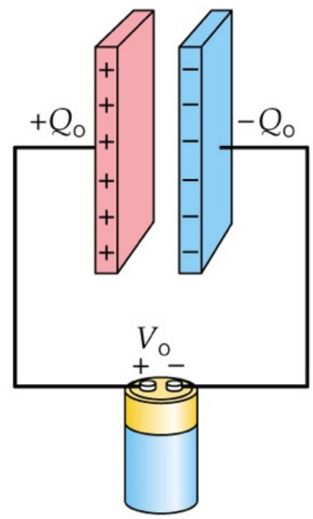
A point charge +Q is fixed as shown.

24. A test charge will be moved from point A to point B.
   A) Follow path I. The shorter path is more efficient because less work will be done.
   B) Follow path II. The longer path is the better choice because more energy will be used.
   C) Follow neither path: choose the path that makes a straight line from A to +Q, then from +Q to B. This is the only path over which no work will be done.
   D) Follow either path, it does not matter. No work will be done no matter what path you choose.
   E) Follow either path. The same amount of work must be done in either case, and it will not be equal to zero.

25. From point A to point B, the potential difference ΔV is
   A) positive. B) negative. C) zero. D) indeterminate.

26. If the fixed charge +Q is replaced by an equal but opposite charge -Q, a test charge at position A will have
   A) a lower potential than the same test charge positioned at point B.
   B) the same potential as an identical test charge positioned at point B.
   C) a higher potential than an identical test charge placed at position B.
   D) zero potential whether positioned at point A or point B, or anywhere at all.

27. What does it mean to say “electrons fall up?”
   A) Electrons are not subject to gravitational forces.
   B) An electron will fall away from another negative charge, from lower potential to higher potential.
   C) An electron will fall toward another negative charge, from a higher potential to a lower potential.
   D) An electron will fall away from a positive charge, from higher potential to 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 $0.20m^2$, a plate separation of 2mm, and is attached to a 6V battery.

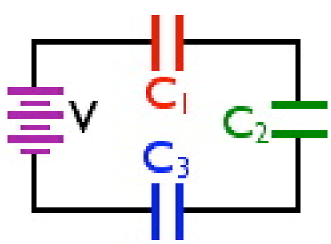
28. If the 6V battery is replaced by a 12V battery, the amount of stored charge
   A) remains constant, and the capacitance increases.
   B) decreases while the capacitance remains constant.
   C) decreases while the capacitance increases.
   D) increases while the capacitance remains constant.
   E) increases while the capacitance increases as well.

29. How does the replacing the battery change the amount of energy stored?
   A) It doesn't; $U = ½Q^2/C$, so the energy remains constant.
   B) Since $U = ½QV$, doubling the voltage doubles the stored energy.
   C) Because $U = ½CV^2$, doubling the voltage quadruples the stored energy.
   D) These answers are all crazy talk. $E = ½mv^2$, but the charges are stationary on the plates. No motion, no energy. The battery is not relevant.

30. Leaving the battery alone now, what is the effect of decreasing the plate separation to 1mm?
   A) The capacitance doubles: $C = 2C_o$. This also doubles the amount of charge that can be stored.
   B) The capacitance halves: $C = ½C_o$. The stored charge must also decrease by half: $Q = ½Q_o$.
   C) Capacitance increases as the square of the separation: $C = 4C_o$. Stored charge decreases to $¼Q_o$.
   D) Capacitance decreases as the inverse square of the separation: $C = ¼C_o$. Charge is unchanged.
   E) The capacitance does not change. You have to change the voltage to get a change in the capacitance.

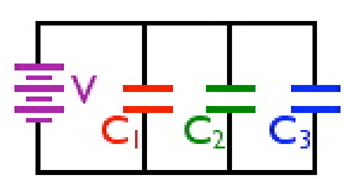
31. Polystyrene (styrofoam) has a dielectric constant $\kappa = 2.6$. What happens to the capacitance when a polystyrene slab is inserted between the plates of the capacitor?
   A) C increases.
   B) C is unchanged.
   C) C decreases.
   D) C = 0 because styrofoam is not a conductor!

32. If the battery remained connected after the capacitor was charged, what was the effect on the stored energy when the polystyrene dielectric material was inserted between the plates?
   A) Since the battery stayed connected, the energy did not change--how could it?
   B) Leaving the battery connected keeps the amount of charge constant, but the dielectric increases the capacitance. The voltage decreases, and as a result, so does the energy.
   C) With the battery is connected, the voltage remains constant. This means that when the dielectric increases the capacitance, the amount of charge increases, and the energy must also increase.



The circuit on the left has a 12V battery connected to three capacitors in series. The capacitances are $C_1 = 3μF$, $C_2 = 6μF$, and $C_3 = 3μF$.

33. Compare the amount of charge stored by each capacitor.
   A) C_1 stores the most charge because it will fill up first when the battery is connected.
   B) C_2 stores the most charge because it has the greatest capacitance.
   C) C_1 and C_3 each store the most charge because they have the same smallest capacitance.
   D) Each capacitor stores the same amount of charge.



34. The same three capacitors are rewired so that they are now in parallel with the original 12V battery. Compare the amount of charge stored by each capacitor.
   A) C_1 stores the most charge because it will fill up first when the battery is connected.
   B) C_2 stores the most charge because it has the greatest capacitance.
   C) C_1 and C_3 each store the most charge because they have the same smallest capacitance.
   D) Each capacitor stores the same amount of charge.

35. Compare the amount of energy stored by C_1 in the parallel circuit to C_1 in the series configuration.
   A) Same capacitor, same battery--same amount of stored energy.
   B) Same capacitor, but C_1 stores more charge in series, so it stores more energy.
   C) The voltage across the parallel C_1 will be higher than across the series C_1. Parallel stores more energy.

36. Does the (+) terminal of a battery actually have a (+) charge?
   A) Sure. What's your point? The (+) terminal has extra protons, and the (-) terminal has extra electrons.
   B) Well, actually, it doesn't. The (+) terminal is actually negative. It's just less negative than the (-) terminal.

37. Current and drift velocity are the same thing.
   A) Sure. What's your point? Let's take the lift down to the carpark, get in the lorry and go down the pub for a pint. Can you watch my jumper while I go to the loo? Just calling something by a different name doesn't make it a different thing.
   B) Current measures the instantaneous velocity of an electron, while drift velocity measures the average velocity. And we know that average and instantaneous velocity are not the same thing.
   C) Drift velocity is a misnomer. It isn't a velocity at all; it really ought to be drift frequency, because it is a measure of how many charges pass a specific point n a given amount of time. Current is actually a measure of how fast the individual charges are moving.
   D) Ok, that's just backwards. Current measures the number of charges per time, while drift velocity measures the speed of the individual charges.

38. The sign convention used for determining the direction of current flow states that
   A) current flows in the direction of the motion of electrons.
   B) current flows in the direction opposite the motion of electrons.
   C) current flows in the direction perpendicular to the motion of electrons.
   D) current flows in whatever direction you draw on your circuit diagram. It doesn't matter because the charges are not actually moving at all.

39. Two wires are made of the same copper. Different lengths, different thicknesses.
   A) The longer wire will have more resistance then the shorter wire.
   B) The thicker wire will have more resistance than the thinner wire.
   C) The wires will have the same resistance, because they are made of the same material.
   D) The wire with the thicker coating of insulation will have greater resistance regardless of the material or geometry of the wire.

40. The resistance of a tungsten bulb filament
   A) increases as the temperature increases.
   B) remains constant regardless of temperature.
   C) decreases as the temperature increases.
   D) may increase or decrease with temperature.

41. Two wires have the same length and the same diameter. One is copper ($\rho_{Cu} = 1.70\text{x}10^{-8}\Omega\cdot\text{m}$), the other is NiChrome ($\rho_{NiCr} = 100\text{x}10^{-8}\Omega\cdot\text{m}$). At room temperature (20°C), the copper wire
   A) will have greater resistance than the NiChrome.
   B) will have a smaller resistance than the NiChrome wire.
   C) will have exactly the same resistance as the NiChrome wire.
   D) cannot be compared to the NiChrome; there is no way to determine which wire will have greater resistance.

42. You have two copper wires of the same length. The first wire has twice the diameter of the second.
   A) The thicker wire will have the greater resistivity.
   B) The thinner wire will have the greater resistivity.
   C) Since they are both copper, they will have the same resistivity.

43. Everybody else is just *green*. Have you seen the charts?
   A) I was in the kitchen. Seamus, that's the dog, was outside.
   B) And then one day you find ten years have got behind you. No one told you when to run.
   C) Not now, John, we've got to get on with the film show. Hollywood waits at the end of the rainbow.
   D) It's a hell of a start. It could be made into a monster, if we all pull together as a team.

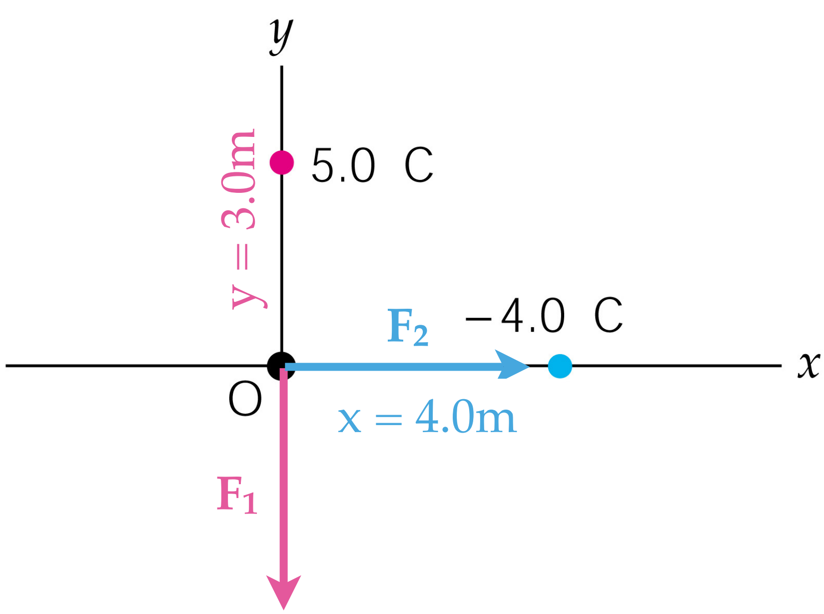
44. ALCS?
   A) Tigers in 4! Wow!
   B) Tigers in 7.
   C) Oakland in 4. (Don't pick this one!)
   D) Oakland in 7.

Problem 01

Two charges are positioned as shown: q_1 = +5.0C and q_2 = -4.0C.

A) (5 points) Calculate the electrostatic **force vector** on a third charge, q_3 = +3.0 C, placed at the origin.

B) (5 points) Determine the **location** for a fourth charge, q_4 = -2.0C, positioned so that the net force on q_3 will be exactly zero.



$$\vec{F} = \vec{F}_1 + \vec{F}_2$$

$$\vec{F} = -\left(\frac{kq_1q_3}{y^2}\right)\hat{\text{j}} + \left(\frac{kq_2q_3}{x^2}\right)\hat{\text{i}}$$

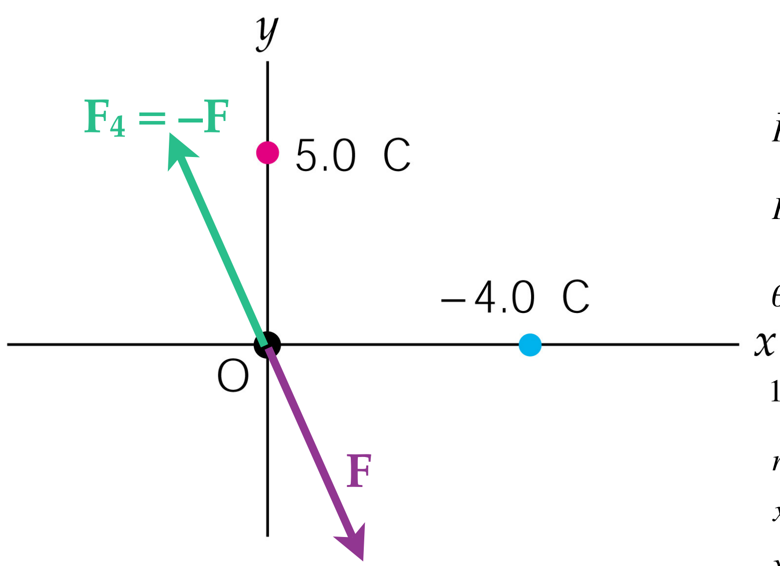
$$\vec{F} = k\left[\left(\frac{q_2q_3}{x^2}\right)\hat{\text{i}} - \left(\frac{q_1q_3}{y^2}\right)\hat{\text{j}}\right]$$

$$\vec{F} = \left(9\times10^9\,\tfrac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left[\left(\frac{(4.0\text{C})(3.0\text{C})}{(4.0\text{m})^2}\right)\hat{\text{i}} - \left(\frac{(5.0\text{C})(3.0\text{C})}{(3.0\text{m})^2}\right)\hat{\text{j}}\right]$$

$$\vec{\text{F}} = \left(6.75\hat{\text{i}} - 15.0\hat{\text{j}}\right)\times10^9\text{N}$$

$$F = \sqrt{F_x^2 + F_y^2} = \sqrt{\left(6.75\times10^9\text{N}\right)^2 + \left(15.0\times10^9\text{N}\right)^2} = 16.5\times10^9\text{N}$$

$$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right) = \tan^{-1}\left(\frac{15}{6.75}\right) = 65.8°\text{ below }+\text{x axis}$$



$$\vec{F}_4 = -\vec{F} = \left(-6.75\hat{\text{i}} + 15.0\hat{\text{j}}\right)\times10^9\text{N}$$

$$F_4 = 16.5\times10^9\text{N} = k\frac{q_3q_4}{r^2}$$

$$\theta_4 = \tan^{-1}\left(\frac{15}{-6.75}\right) = 65.8°\text{ above }-\text{x axis}$$

$$16.5\times10^9\text{N} = \left(9\times10^9\,\tfrac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\frac{(3.0\text{C})(2.0\text{C})}{r^2}$$

$r = 1.81$m at 114.2° (2nd quadrant)

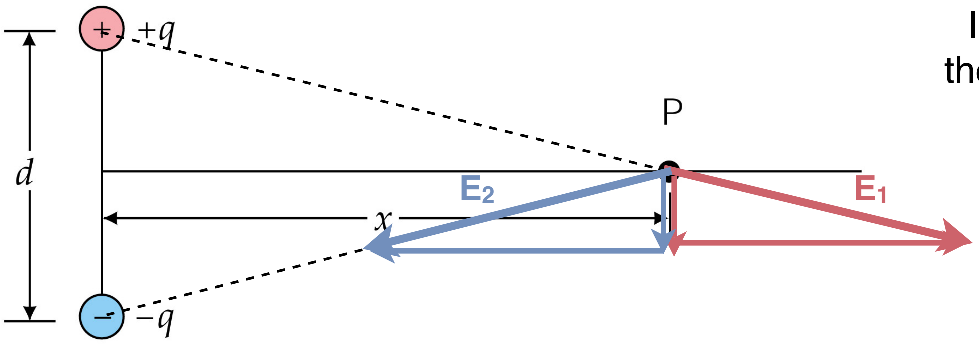
$$x = -r\cos\theta_4 = -(1.81\text{m})\cos65.8° = -0.743\text{m}$$

$$y = r\sin\theta_4 = (1.81\text{m})\sin65.8° = 1.65\text{m}$$

$$\vec{r} = \left(-0.74\hat{\text{i}} + 1.65\hat{\text{j}}\right)\text{m}$$

Problem 02

The dipole shown consists of two equal and opposite 5.0μC charges separated by a distance d = 2.0cm. Determine the **electric field vector** at point P located at x = 4.0cm.



If charges are equal, then magnitude $E_1 = E_2$
E_{1x} cancels E_{2x}
E_{1y} adds with E_{2y}
$\mathbf{E} = -(E_{1y} + E_{2y})\hat{\mathbf{j}}$

$$r^2 = x^2 + \left(\frac{d}{2}\right)^2$$

$$r^2 = (0.04\text{m})^2 + \left(\frac{0.02\text{m}}{2}\right)^2$$

$$r^2 = 0.0017\text{m}^2$$

$$\tan\theta = \frac{\left(\frac{d}{2}\right)}{x}$$

$$\theta = \tan^{-1}\left(\frac{d}{2x}\right) = \tan^{-1}\left(\frac{0.02}{0.08}\right)$$

$$\theta = 14.0°$$

$$\vec{E}_1 = \left(\frac{kq}{r^2}\right)\left(\cos\theta\hat{\mathrm{i}} - \sin\theta\hat{\mathrm{j}}\right)$$

$$\vec{E}_2 = \left(\frac{kq}{r^2}\right)\left(-\cos\theta\hat{\mathrm{i}} - \sin\theta\hat{\mathrm{j}}\right)$$

$$\vec{E} = \vec{E}_1 + \vec{E}_2$$

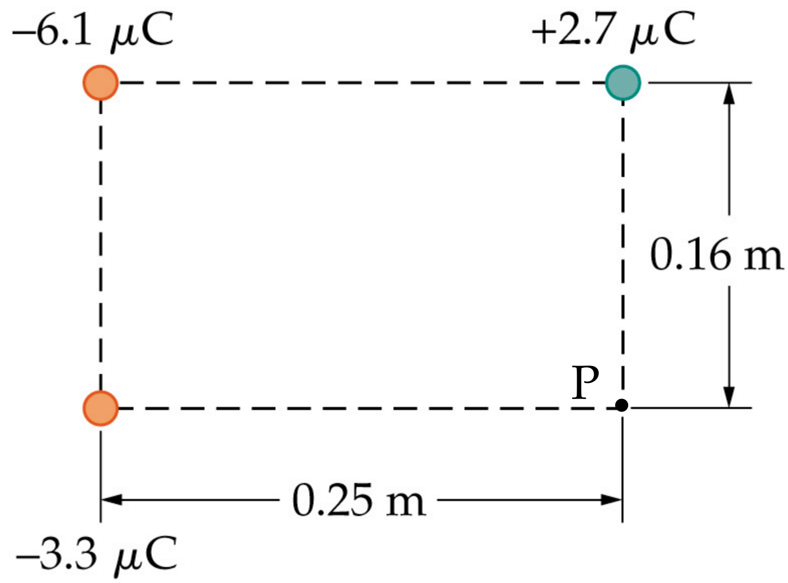
$$\vec{E} = -2\left(\frac{kq}{r^2}\right)(\sin\theta)\hat{\mathrm{j}}$$

$$\vec{E} = -2\left(\frac{\left(9\times10^9\,\frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left(5\times10^{-6}\text{C}\right)}{(0.04\text{m})^2 + (0.01\text{m})^2}\right)(\sin 14°)\hat{\mathrm{j}}$$

$$\vec{E} = -\left(1.28\times10^7\,\tfrac{\text{N}}{\text{C}}\right)\hat{\mathrm{j}}$$

Problem 03

A) (5 points) How much work must be done to assemble the charges as shown?
B) (5 points) Determine the voltage at point P.



$q_1 = -6.1\mu\text{C}$

$q_2 = +2.7\mu\text{C}$

$q_3 = -3.3\mu\text{C}$

$$U = U_{12} + U_{13} + U_{23}$$

$$U = k\left[\frac{q_1 q_2}{r_{12}} + \frac{q_1 q_3}{r_{13}} + \frac{q_2 q_3}{r_{23}}\right]$$

$$U = \left(9\times10^9 \tfrac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left[\frac{(-6.1\times10^{-6}\text{C})(+2.7\times10^{-6}\text{C})}{(0.25\text{m})} + \frac{(-6.1\times10^{-6}\text{C})(-3.3\times10^{-6}\text{C})}{(0.16\text{m})} + \frac{(+2.7\times10^{-6}\text{C})(-3.3\times10^{-6}\text{C})}{\sqrt{\left[(0.16\text{m})^2 + (0.25\text{m})^2\right]}}\right]$$

$$U = 0.269\text{J}$$

$$V = V_1 + V_2 + V_3$$

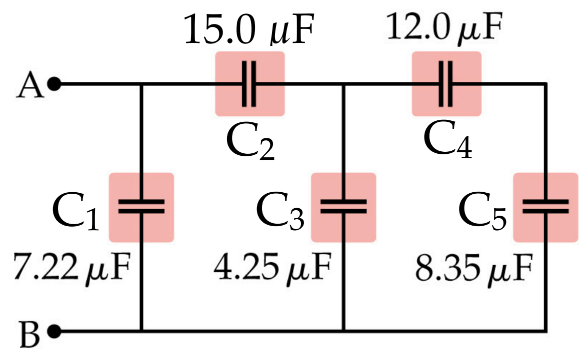
$$V = k\left[\frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{r_3}\right]$$

$$V = \left(9\times10^9 \tfrac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left[\frac{(-6.1\times10^{-6}\text{C})}{\sqrt{\left[(0.16\text{m})^2 + (0.25\text{m})^2\right]}} + \frac{(+2.7\times10^{-6}\text{C})}{(0.16\text{m})} + \frac{(-3.3\times10^{-6}\text{C})}{(0.25\text{m})}\right]$$

$$V = -1.52\times10^5 V$$

Problem 04

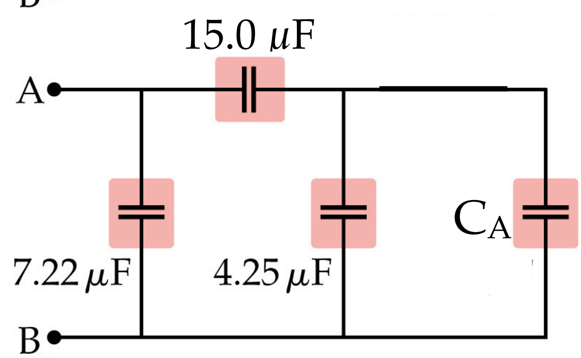
A) (6 points) Find the equivalent capacitance if leads A and B are connected to a 12.0V battery.



- Replace C_4 and C_5 (series) with C_A.

$$\frac{1}{C_A} = \frac{1}{C_4} + \frac{1}{C_5} = \frac{1}{12.0\mu\text{F}} + \frac{1}{8.35\mu\text{F}}$$

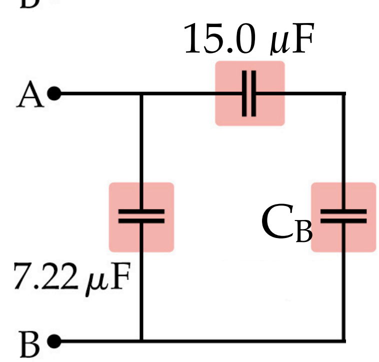
$$C_A = 4.92\mu\text{F}$$



- Replace C_3 and C_A (parallel) with C_B.

$$C_B = C_3 + C_A = 4.25\mu\text{F} + 4.92\mu\text{F}$$

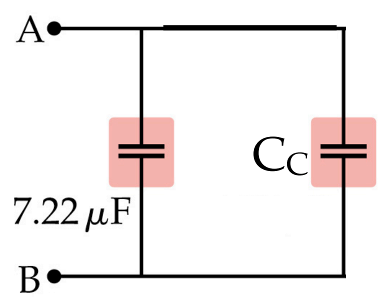
$$C_B = 9.17\mu\text{F}$$



- Replace C_2 and C_B (series) with C_C.

$$\frac{1}{C_C} = \frac{1}{C_2} + \frac{1}{C_B} = \frac{1}{15.0\mu\text{F}} + \frac{1}{9.17\mu\text{F}}$$

$$C_A = 5.69\mu\text{F}$$



- Replace C_1 and C_C (parallel) with C_D.

$$C_D = C_1 + C_C = 7.22\mu\text{F} + 5.69\mu\text{F}$$

$$C_D = 12.91\mu\text{F}$$

B) (4 points) Calculate the total amount of charge and the total energy stored.

$$Q = C_D V = (12.91\mu\text{F})(12.0\text{V})$$

$$Q = 155\mu\text{C}$$

$$U = \tfrac{1}{2} C_D V^2 = \tfrac{1}{2}(12.91\mu\text{F})(12.0\text{V})^2$$

$$U = 930\mu\text{J}$$

C) (4 points) Bonus: Find the voltage across and the amount of charge stored on each capacitor.

$$V_1 = 12\text{V}$$

$$Q_1 = C_1 V_1 = (7.22\mu\text{F})(12.0\text{V})$$

$$Q_1 = 86.6\mu\text{C}$$

$$V_C = 12\text{V}$$

$$Q_C = C_C V_C = (5.69\mu\text{F})(12.0\text{V})$$

$$Q_2 = Q_c = 68.3\mu\text{C}$$

$$V_2 = \frac{Q_2}{C_2} = \frac{(68.3\mu\text{C})}{(15.0\mu\text{F})} = 4.6\text{V}$$

$$V_2 + V_3 = 12\text{V}$$

$$V_3 = 12\text{V} - 4.6\text{V} = 7.4\text{V}$$

$$Q_3 = C_3 V_3 = (4.35\mu\text{F})(7.4\text{V}) = 31.6\mu\text{C}$$

$$V_A = V_3 = 7.4V$$

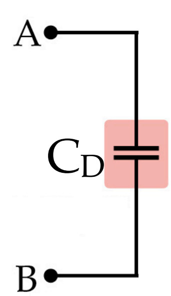
$$Q_A = C_A V_A = (4.92\mu\text{F})(7.4\text{V}) = 36.6\mu\text{C}$$

$$Q_4 = Q_A = 36.6\mu\text{C}$$

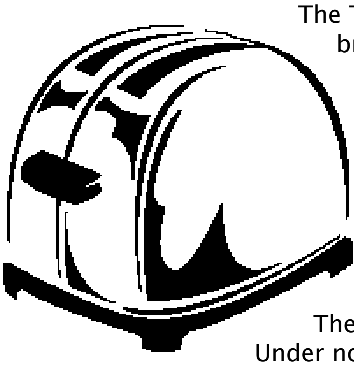
$$V_4 = \frac{Q_4}{C_4} = \frac{(36.6\mu\text{C})}{(12.0\mu\text{F})} = 3.0\text{V}$$

$$Q_5 = Q_A = 36.6\mu\text{C}$$

$$V_5 = \frac{Q_5}{C_5} = \frac{(36.6\mu\text{C})}{(8.35\mu\text{F})} = 4.4\text{V}$$



Problem 05



The Toast Advisory Board recommends a minimum daily requirement of two slices, nicely browned with butter and marmalade (the American Association for the Advancement of Jams and Jellies (AAAJAJ) finds most berry preserves an acceptable substitute). More than two slices are recommended if the bread is not whole wheat or a whole grain blend. Most people do not meet this minimum requirement, and suffer from Toast Deficiency Syndrome (TDS). This devastating condition knows no bounds: young and old alike, men and women. Even little children are affected! You may be a victim of TDS and not even know it. Symptoms include, but are not limited to, mid-morning hunger and a "growling" stomach. Fortunately, TDS is easily cured! Remember: two slices, butter and marmalade.

The toaster shown has a copper heating filament (**ρ = 1.70x10$^{-8}\Omega\cdot$m, α=6.8x10^{-3}/°C**). Under normal operating conditions, the toaster is rated at **960W** in a **120V** circuit. The filament breaks (it's a pretty old toaster), but your dad decides to fix it instead of buying a new one. He somehow manages to find the soldering iron, and you're back in business before the detrimental effects of TDS start to impair anyone's judgement. However, your dad **decreased the filament length by 5%**.

A) (4 points) Find the current through and resistance of the toaster filament prior to the repair.

$$P = 960\,\text{W}$$
$$V = 120\,\text{V}$$

$$P = IV$$
$$960\,\text{W} = I(120\,\text{V})$$
$$I = 8\,\text{A}$$

$$P = \frac{V^2}{R}$$
$$960\,\text{W} = \frac{(120\,\text{V})^2}{R}$$
$$R = 15\Omega$$

B) (3 points) What is the new resistance after the filament length is decreased?

$$R_o = \rho\frac{L_o}{A}$$
$$R_f = \rho\frac{L_f}{A}$$
$$L_f = (0.95)L_o$$

$$R_f = \rho\frac{(0.95)L_o}{A}$$
$$R_f = (0.95)\rho\frac{L_o}{A} = (0.95)R_o$$
$$R_f = (0.95)(15\Omega) = 14.25\Omega$$

C) (3 points) Does this increase or decrease the toasting temperature? By how much (ΔT=?)?

$$R_f = R_o(1+\alpha\Delta T)$$
$$R_f - R_o = R_o(\alpha\Delta T)$$
$$\Delta T = \frac{(R_f - R_o)}{(\alpha R_o)}$$

$$\Delta T = \frac{(14.25-15)}{(6.8\times10^{-3\circ}\text{C}^{-1})(15)}$$
$$\Delta T = -7.4^\circ\text{C}$$