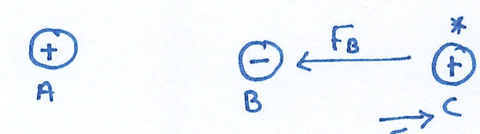
Electric Fields and Forces Review Notes

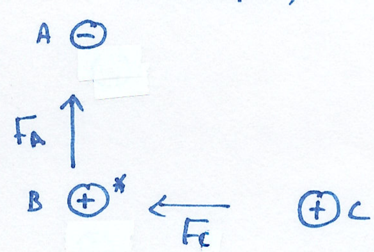
- Three methods of charging an object
    1. Charging by friction → re-arrangement of electrons
    2. Charging by induction (no contact)
    3. Charging by contact (equal sharing of charges/conservation of charge)
- Difference of electron movement in a conductor vs. an insulator
- Electroscopes
- Coulomb's Law
    - Describes the relationship between the force created on two charges depending on the distance between the charges
    - $F_e = \frac{kq_1q_2}{r^2}$
    - Do not include the signs on the charges in the equation. You need to determine the direction yourself based on electrostatic repulsion/attraction. *Don't get this confused with the direction of electric fields!*
    - When determining the net/total force and direction on a charged object due to the presence of other charges, pretend the charge that you are trying to find the net force on is mobile and all other charges are stationary (ie. direction is found based off electrostatic repulsion & attraction).
    - Use trig. and Pythagoreans theory for 2-D problems

Linear (example)



F_{net} on C $= (-F_B) + (F_A)$

2D (example)



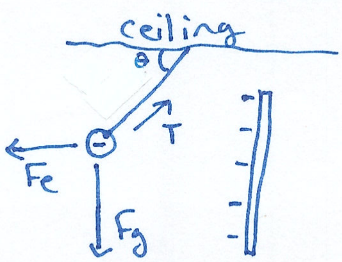
$a^2 + b^2 = c^2$

F_{net} on B $= \sqrt{(F_A)^2 + (F_C)^2}$

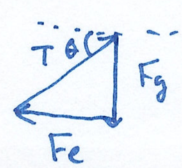
* remember angle for direction!

- Free-body diagram problems

(example)

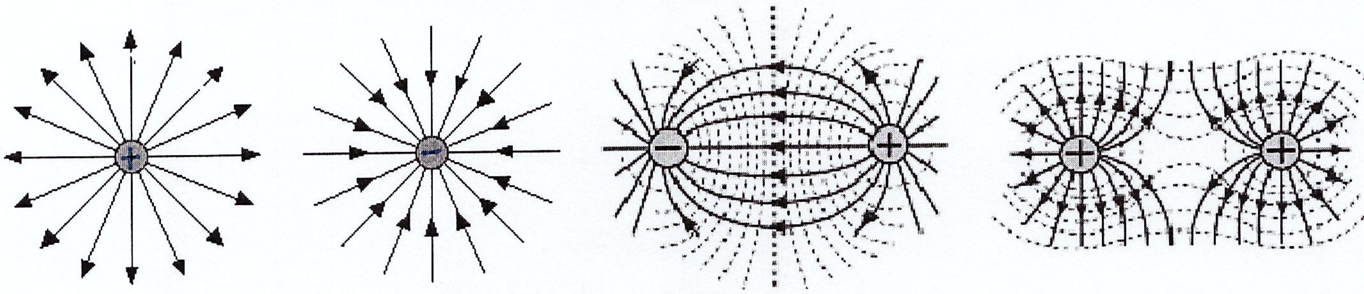


re-draw tip-to-tail



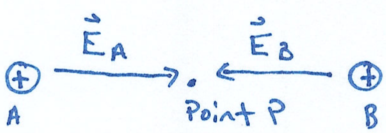
use trig & Pythagoreans to solve unknown.

- Electric Field Lines
  - Electric field lines always point towards a negative charge and always point out/away from a positive charge



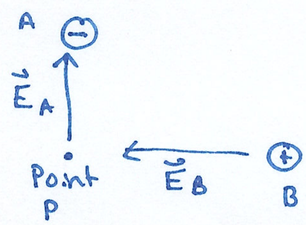
- For a point charge *producing* an electric field use $\vec{E} = \frac{kq}{r^2}$
  - Need to be able to calculate the net electric field strength at a particular point when multiple charges are present (both linear and 2D problems)

Linear (example)



$\vec{E}$ at point P $= \vec{E}_A + (-\vec{E}_B)$

2D (example)



$a^2 + b^2 = c^2$

$\vec{E}$ at point P $= \sqrt{(\vec{E}_A)^2 + (\vec{E}_B)^2}$

* remember angle for a direction! *

- For a charge *experiencing* a force due to an existing electric field use $\vec{E} = \frac{F_e}{q}$
- Questions relating speed and voltage of a charged particle in a uniform electric field should be solved using energies

$$E_k = \frac{1}{2}mv^2 \text{ and } \Delta V = \frac{\Delta E}{q}$$ ← energy, not electric field!   where $\Delta E = E_f - E_i$

  - Remember eV is a unit of energy ($1\text{eV} = 1.6\text{x}10^{-19}\text{J}$)

- Parallel Plates
  - ***Never use*** the equation $\vec{E} = \frac{kq}{r^2}$ for parallel plates/uniform electric fields
  - Between parallel plates, the electric field is uniform, but the voltage is changing
  - The following equations ***can be used*** for parallel plates/uniform electric field questions

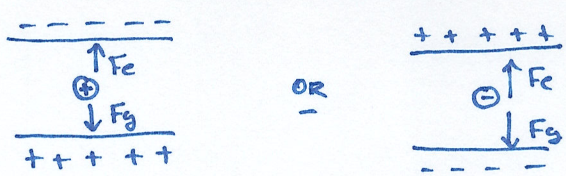
$$\vec{E} = \frac{\Delta V}{d} \qquad \vec{E} = \frac{F_e}{q} \qquad \Delta V = \frac{\Delta E}{q}$$ where $\Delta E = E_f - E_i$

- Projectile-like motion of charged particles in a uniform field/parallel plates
    - Motion *parallel to electric field* is accelerated (use accelerated equations from physics 20).
        - Any information concerning the electric field, electric force, voltage/potential difference is tied into the accelerated motion.
        - Can use forces or energies to solve these types of problems, but be careful with using energies & voltages because the voltage is changing between the plates at different distances
        - Force of gravity (F_g) can be ignored for atomic/subatomic particles (therefore $F_{net} = F_e$)
    - Motion *perpendicular to electric field* is uniform motion (use constant velocity equation $v = \frac{d}{t}$). The particle already had some perpendicular speed (ie. shot into the area between the plates).
    - Time is the same for the parallel and perpendicular motion

- Current $I = \frac{q}{t}$

- Millikan's Oil Drop Experiment
    - Start with a free-body diagram to determine direction of forces acting an particle
    - Force of gravity (F_g) **cannot be ignored** because the oil drop is **not an atomic/subatomic particle**
    - $F_e = F_g$ if particle is stationary or constant velocity (ie. acceleration = 0.0m/s^2, then F_{net} = 0.0N)

      $\vec{E}q = mg$

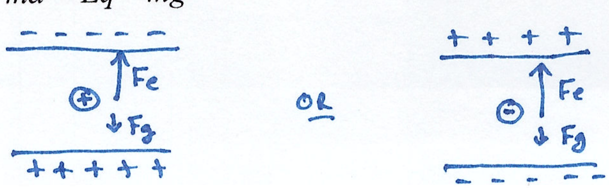


- $F_{net} = F_e + F_g$ if the particle is accelerating down

  $ma = \vec{E}q + mg$

- $F_{net} = F_e + (-F_g)$ if the particle is accelerating up

  $ma = \vec{E}q - mg$



Electric Forces and Fields Review Questions

1.) A and B are identical pith balls. Ball A has a charge of -3.00μC, and ball B has a charge of -1.00μC. If these two balls are brought into brief contact with each other, and then separated to a distance of 2.00×10^{-2}m, what is the electric force on ball A?

a. 33.7N
b. 45.0N
c. 67.4N
d. 89.9N

2.) Two point charges are initially 6.0cm apart, and are then moved so that they are 2.0cm apart. If the initial force between these two point charges was F, what is the new force?

a. 0.11 F
b. 0.33 F
c. 3.0 F
d. 9.0 F

3.) A negatively charged rubber rod is used to charge an electroscope by induction and grounding. Once the charging process is complete and the rod has been removed, the nature of charge on the electroscope head will be ___i___ and the nature of the charge on the electroscope leaves will be ___ii___.

The statement above is correctly completed by which row?

Row	i	ii
a.	positive	negative
b.	negative	positive
c.	negative	negative
d.	positive	positive

4.) If an alpha particle is accelerated from rest through a potential difference of 2.00×10^3 V, what is the maximum speed?

a. 3.10×10^5 m/s
b. 4.39×10^5 m/s
c. 2.65×10^7 m/s
d. 2.53×10^8 m/s

5.) What is the total number of electrons that pass through a conductor each minute if it carries a current of 0.20A?

a. 0.20
b. 12
c. 1.9×10^{18}
d. 7.5×10^{19}

6.) An electron is placed in a strong uniform electric field between two charged plates. The direction of the acceleration of the electron will be

a. in the direction of the electric field.
b. in the opposite direction of the electric field .
c. perpendicular to the electric field.
d. in the direction of the gravitational field

7.) Millikan determined the elementary charge by finding the charge on an oil drop. He did this by balancing the electric force and gravitational force acting on the oil drop and deriving the formula

a. $q = \frac{mg}{\Delta V d}$

b. $q = \frac{mgd}{\Delta V}$

c. $q = \frac{F_g \Delta V}{d}$

d. $q = \frac{F_g \Delta V}{gd}$

8.) A gold-leaf electroscope is used by a student to determine the nature of the static charge on a plastic rod. The procedure involves the following steps:

I. the electroscope is grounded
II. a rubber rod with known static charge is brought near the electroscope
III. the plastic rod with unknown static charge is brought near to the electroscope and removed
IV. the ground is removed from the electroscope
V. the rubber rod is moved away from the electroscope

The order that the student should follow if she is to determine the nature of the charge on the plastic rod is:

a. I, II, V, III, IV
b. II, I, IV, V, III
c. I, II, V, IV, III
d. III, I, IV, II, V

9.) A point charge of magnitude 6.9×10^{-5} C produces an electric field of 1.0×10^{3} N/C at point P. The distance from the point charge to point P is

a. 4.3×10^{-2} m
b. 2.1×10^{-1} m
c. 2.5×10^{1} m
d. 6.2×10^{2} m

10.) Objects A and B both have a mass of 5.00×10^{-4} kg and a charge of +3.00μC. If object A is brought to a distance of 2.00×10^{-2}m from object B and released, what is the initial acceleration of object A?

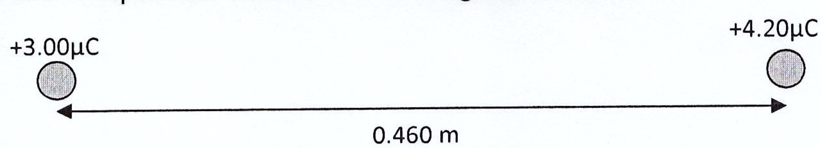
a. 4.05×10^{5} m/s^2
b. 2.02×10^{5} m/s^2
c. 8.09×10^{2} m/s^2
d. 1.01×10^{2} m/s^2

11.) If the electric field strength at a point 1.50m from a charged point source is 2.70×10^4 N/C, what is the magnitude of electric field strength at a point 0.750 m from the same source?

12.) If an alpha particle experiences an electrical force of 0.250N at a point in space, what magnitude of electric force would a proton experience at the same point?

13.) Calculate the magnitude of electric force between two point charges of 2.00μC and 2.70μC that are 0.100m apart.

14.) Calculate the electric field strength mid-way between two point charges that are 0.460 m apart as shown in the diagram below.



15.) The potential difference between two parallel plates which are 13.0cm apart is 7.10V. If an alpha particle is placed between these plates, what is the magnitude of acceleration of the alpha particle?

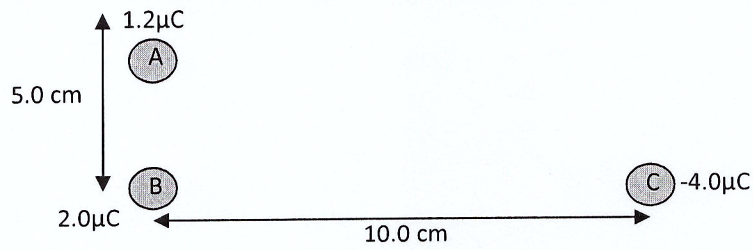
16.) An electric field of 2.10×10^3 N/C is produced by two parallel plates 5.00cm apart from each other. Calculate the work done against the electric field if a charged particle of 5.50μC is moved 3.00cm perpendicular to the electric field.

17.) An electric field of 2.10×10^3 N/C is produced by two parallel plates 5.00cm apart from each other. Calculate the work done against the electric field if a charged particle of 5.50μC is moved 3.00cm parallel to the electric field.

18.) If an alpha particle is accelerated from rest through a distance of 4.00cm by a uniform electric field in 2.50×10^{-5} s, what is the electric field strength?

19.) In Millikan's oil drop experiment, an oil drop having a mass of 6.00×10^{-17} kg is accelerating upward at a rate of 6.40m/s^2 when sprayed between two horizontal parallel plates 5.00cm apart. The top plate has a positive charge and the bottom plate has a negative charge. If the potential difference between the plates is 90.0V, what is the charge on the oil drop?

20.) Three charged objects are at the corners of a triangle as shown in the diagram.



What is the electric force acting on charge B due to the other two charges?

Answers:

1. D
2. D
3. D
4. B
5. D
6. B
7. B
8. B
9. C
10. A
11. 1.08×10^5 N/C
12. 0.125 N
13. 4.85 N
14. 2.04×10^5 N/C, left
15. 2.63×10^9 m/s^2
16. 0 J because the electron is moving perpendicular to the electrical force/field
17. 3.47×10^{-4} J
18. 2.66 N/C
19. 5.40×10^{-19} C
20. 11N, 40° E of S (or 11N, 50° S of E)