Lab: AP Review Sheets AP Physics

Chapter 5 - Electric Forces and Fields Ilan Brusselaers

Background: This unit focuses on electric charges, forces, and fields. Electric charges experience forces in electromagnetic fields and an excess or lack of electrons can determine the charge. Electric forces are caused by electric charges and repel or attract those charges. (Like charges repel, opposing attract.) An electric field is a physical field that surrounds charged particles that indicates the force that would act on a unit positive test charge if placed at that location.

Major Topics:

Electric Charge

- Charge is dependent on the subatomic particles that make up matter. Atoms contain positively charged protons and negatively charged electrons. When an atom is neutral, the amount of electrons and protons are the same. The charge of an atom can be changed by the addition or removal of ions (protons don't change) which turns the atom into an ion.
- Conductivity, the measure of a material's ability to conduct a current, depends on how tightly electrons are bound to the nucleus of the atom. In conductors electrons are loosely tied, allowing charges to be conducted easily. In non-conductors electrons are tightly bound and charges are difficult to conduct.
- Electrons are the only subatomic particles that can freely move and thus are the way that charges move in and between objects. The movement of negative charge is the direction in which electrons move and the movement of positive charge is the direction opposite of which electrons move.
- Charging by conduction is the movement of electrons from a charged conductor to another conductor of a different charge when the two touch.
- Charging by induction is the polarization of charges due to a charged conductor being near a neutral conductor.
- Grounding is the connection between a conductor and the ground/the earth. Charges flow through the earth, but the net effect of what happens depends on the situation.

Coulomb's Law

- Coulomb's Law is an equation used to find the force of attraction or repulsion between two charges. In scenarios with more than 2 charges, the net force can be found through adding all vector components of all the charges.
- It is written as

$$\vec{F}_{21} = k\frac{q_1q_2}{r^2}\hat{r}$$

- F_{21} = the force on charge 2 from charge 1

- k = the electric constant 8.99e[9] N m^2/C^2
- q_1 and q_2 = the charges in Coulombs, a positive or negative value
- r = the distance between the two charges
- $\hat{r}$ = the unit vector that points from charge 1 towards charge 2

Electric Fields

- Electric charges produce electric fields around them in which all charges in said field experience an electric force.
- In the electric field of charge q (in which charge q is magnitudes larger than charge Q to the point where the electric force acting on charge q from charge Q is negligible), charge Q is acted on by an electric force through the equation

$$F_e = k\frac{qQ}{r^2}$$

- The electric field is the electric force with the charge Q divided out so that

$$\vec{E} = \int k\frac{dq}{r^2}\,\hat{r}$$

- These equations only work in constant electric fields. In order to find the electric field of continuous charges

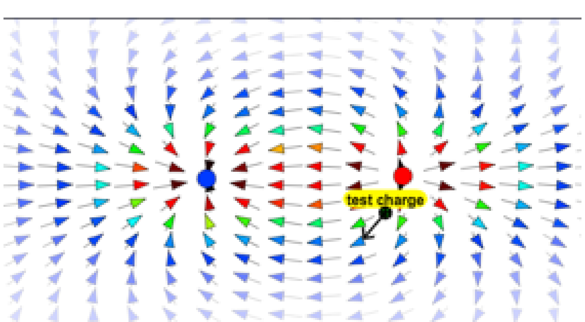
$$E = \frac{F_e}{Q} = k\frac{q}{r^2}$$

- Where dq needs to be manipulated to a type of length/radius/etc… in order to integrate.
  - $dq = \lambda\, dL$ $\qquad$ $dq = \sigma\, dA$ $\qquad$ $dq = \rho\, dV$

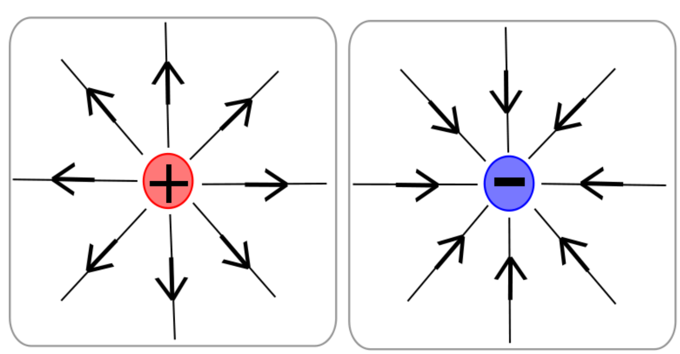
Visualizing Electric Fields

- There are two ways of diagrams used to visualize electric fields; field vectors and field lines.
  - Field Vectors: regularly-spaced vectors indicate the direction of the electric field at that point, while the color or shading of the vector indicates its relative magnitude
  - Field Lines: lines are drawn away from positive charges toward negative charges, with tangents to the lines indicating the direction of the electric field; the density of the field lines in space indicates relative magnitude, with more closely-spaced lines near the charges indicating a greater field strength there

Field Vectors

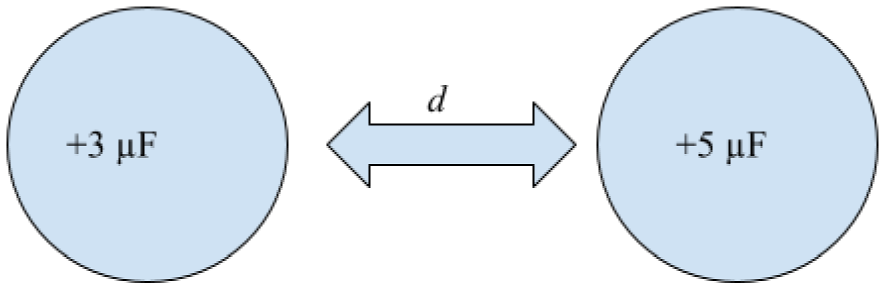


Field Lines

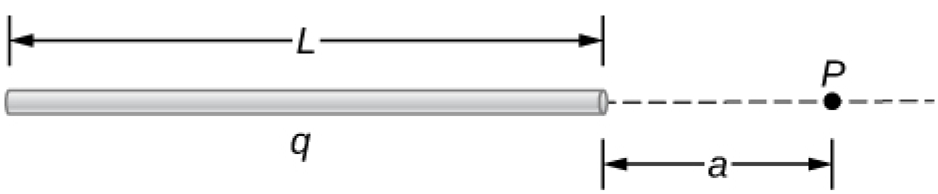


Questions:

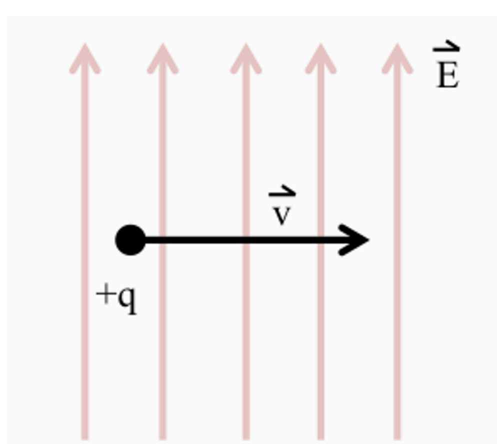
1. Two point particles with charges $+3\mu C$ and $+5\mu C$ are held in place by 3-N forces on each charge in appropriate directions. (a) Draw a free-body diagram for each particle. (b) Find the distance between the charges.



2. The charge per unit length on the thin rod shown below is λ. What is the electric field at the point P?



3. A positive charge q is released from rest at the origin of a rectangular coordinate system and moves under the influence of the electric field $\hat{E}=E_0(1+x/a)\hat{\imath}$. What is the kinetic energy of q when it passes through x=3a?

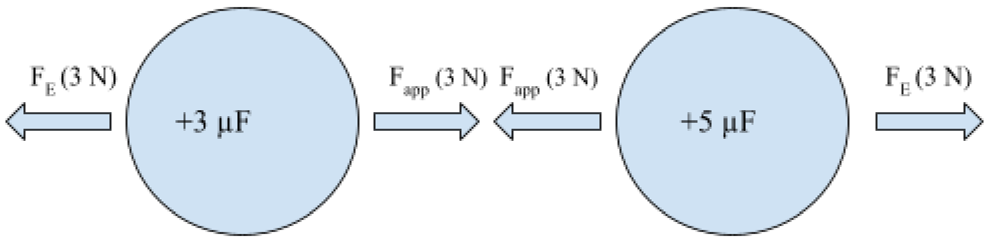


Answers:

1.

a. Draw a free body diagram

Held in place → $F_{app} = F_E$



b. Find the distance between the charges

$$\vec{F}_{21} = k\frac{q_1 q_2}{r^2}\hat{r} \quad \rightarrow 3 = \frac{(8.99\times10^9)(3.0\times10^{-6})(5\times10^{-6})}{r^2}$$

$$r = \sqrt{\frac{(8.99\times10^9)(3.0\times10^{-6})(5\times10^{-6})}{3}} \quad \rightarrow \quad r = 0.21\ m$$

2.

$$\lambda = \frac{q}{L} \qquad dq = \lambda dx$$

$$\vec{E} = \int k\frac{dq}{r^2}\hat{r}$$

$$E = \int_a^{a+L} k\frac{\lambda}{x^2}dx$$

$$E = \lambda k \int_a^{a+L} \frac{1}{x^2}dx$$

$$E = \lambda k(\frac{1}{L+a} - \frac{1}{a})$$

3.

F= qE → F=qE_0(1+x/a)î

$$W = \int F \cdot dx \rightarrow W = \int_0^{3a} qE_0(1+x/a)\hat{i}\ dx$$

$$W = qE_0(3a + \frac{1}{2a}(3a)^2) \rightarrow W = qE_0(\frac{15a}{2})$$

$$W = KE \rightarrow KE = qE_0(\frac{15a}{2})$$