## Unit 3 - Electrical Theory and Basic Circuits <br> Chapters 15-18 of your textbook

## Unit 3.A - Electric Charge, Forces, and Fields

## 3.A. 1 Problems - Electric Charge and Charging

 Section 15.1-15.2 of your textbook.1. What is the net charge of an object that has lost 5.0 billion electrons?

| Early E. C.: I 1 |  |
| :---: | :---: |
| Total HW Points |  |
| Unit 3.A: | 126 |
| Total Lab Points |  |
| Unit 3.A: | 134 |
| Unit 3.A Apps | 15 |
| Late, Incomplete, Units Fee? | Work, No |


| Possible 3.A.1 Pts.: | 7 |  |
| :--- | ---: | :---: |
| Late, Incomplete, No work, |  |  |
| No Units Fee: | -1 | -2 |
| Final Score: | 7 |  |

2. In walking across a carpet, you acquire a net negative charge of $85 \mu \mathrm{C}$. How many excess electrons do you have?

An alpha particle is the nucleus of a helium atom with no electrons.
3. What would be the charge (in Coulombs) on two alpha particles?
4. How many electrons would you need to add to make one alpha particle into a helium atom?

A glass rod rubbed with silk acquires a charge of $+5.0 \mathrm{E}-12 \mathrm{C}$.
5. Is the charge on the silk (1) positive, (2) zero, or (3) negative? Why?
6. What is the charge on the silk, and how many electrons have been transferred to the silk?
7. How much mass has the glass rod gained or lost?

| Possible 3.A. 2 Pts.: | $\mathbf{6}$ |  |
| :--- | ---: | ---: |
| Late, Incomplete, No work, |  |  |
| No Units Fee: | $-1-2$ | -3 |
| Final Score: | 6 |  |

## 3.A. 2 Problems - Electric Force Section 15.3 of your book.

1. An initially neutral electroscope is charged by induction by bringing near a positively charged object. If 3.22 E 8 electrons flow through the ground wire and the ground wire is then removed, what is the net charge on the electroscope? Be sure to indicate whether it's a positive negative charge.

Two identical point charges are a fixed distance apart. By what factor would the magnitude of the electric force between them change if
2. One of their charges were doubled and the other halved,
3. Both their charges were halved,
4. One charge was halved and the other left unchanged?
5. One charge is doubled, and the radius is doubled too.
6. The distance between neighboring singly charged sodium and chloride ions in crystals of table salt $(\mathrm{NaCl})$ is $2.82 \mathrm{E}-10 \mathrm{~m}$. What is the attractive electric force between the ions?

# Possible 3.A. 3 Pts.: 5 Late, Incomplete, No work, <br> <br> 3.A. 3 Problems - Electric Fields <br> <br> 3.A. 3 Problems - Electric Fields Section 15.4 of your textbook. 

 Section 15.4 of your textbook.}

1. If the distance from a charge is doubled, is the magnitude of the electric field (1) increased, (2) decreased, or (3) the same compared to the initial value? Explain your answer.
2. If the original electric field due to a charge is $1.0 \mathrm{E}-14 \mathrm{~N} / \mathrm{C}$, what is the magnitude of the new electric field at twice the distance from the charge?
3. An electron is acted on by two electric forces, one of $2.7 \mathrm{E}-14 \mathrm{~N}$ acting upward and a second of $3.8 \mathrm{E}-14 \mathrm{~N}$ acting to the right. What is the magnitude of the electric field at the electron's location?
4. At what distance from a proton is the magnitude of its electric field $1.0 \mathrm{E} 5 \mathrm{~N} / \mathrm{C}$ ?
5. Consider two points in space, $A$ and $B$, located different distances from the same charge, q. If point A is triple the distance from the charge as point B , what percentage of the electric field is point A when compared to point B ?

| Possible 3.A. 4 Pts.: | 8 |
| :--- | ---: |
| Late, Incomplete, No work, |  |
| No Units Fee: | $-1-2$ |
| Final Score: | 8 |

## 3.A. 4 Problems - Conductors, Gauss' Law Section 15.5-15.6 of your textbook.

A solid conducting sphere is surrounded by a thick, spherical conducting shell. Assume that a total charge +Q is placed at the center of the sphere and released.

1. In terms of Q , how much charge is on the interior of the sphere?
2. How much charge is on the surface of the sphere?
3. The inner surface of the shell?
4. The outer surface of the shell?

In the previous problem, what is the electric field direction:
5. In the interior of the solid sphere?
6. Between the sphere and the shell?
7. Inside the shell?

Outside the shell?
8. Suppose a Gaussian surface encloses both a positive point charge of $+1.5 \mathrm{E}-12 \mathrm{C}$ and a negative point charge of $-6.0 \mathrm{E}-12 \mathrm{C}$. Draw this surface with an appropriate number of field lines passing through it.

# AP Physics 2 <br> Unit 3.A. 1 Lab - Electric Charge 

## Reminder: Update Table of Contents

Half

## Lab Overview:

Students determine the charges on different materials comparatively, based on Benjamin Franklin's arbitrary but accepted pronouncement that a glass rod gets a positive charge, and silk gets a negative charge after they are rubbed together.

## Possible Materials:

Silk
Rabbit fur
Black Plastic rod
Glass rod OR acrylic rod
Polyethylene tubing

| Charging Lab (3.A.1) Guide |  |  |
| :---: | :---: | :---: |
| Table of Contents, Title/Date, Detailed <br> Synopsis, Two Purposes | $/ 2$ |  |
|  | Comparative Data | $/ 2$ |
|  | Tidy Table | $/ 1$ |
|  | Labeled Table | $/ 1$ |
|  | Logical Series | $/ 4$ |
| Question 1: Methods Used. |  | $/ 2$ |
| Question 2: Difficulties Encountered. | $/ 2$ |  |
| Late Lab Fee: |  |  |
| Total: |  | $-\mathbf{1 4}$ |

Wooden rod
Balloon
Cotton
Wool

## Mission 1:

By rubbing dissimilar materials together, and using Franklin's basis that glass is positive and silk is negative, build a triboelectric series for as many of the materials as you can. It will be a relative scale - base your rankings on deduction and data.

Points will be assessed based on your comparative data set, and your resulting triboelectric series, in a tidy, well labeled table. Be sure to indicate which end of your table is positive, and which is negative.

## Questions: 2 Points Each

1. What methods did you use to determine your triboelectric series?
2. What difficulties did you have determining your series?

## AP Physics 2

## Reminder: Update Table of Contents

Half

## Lab Overview:

Students charge two balloons hanging from threads to determine the magnitude of electric force.

## Materials:

Construction Equipment
Two small balloons
Lightweight flexible thread
Piece of fabric.
Very good scale.

## Mission 1:

Include all the following data in a tidy, wellorganized, labeled data table.

Connect the balloons to identical-length measured threads, and obtain their masses. Then, hang them from the cantilevered rod of a construction setup. Have the balloons out over an edge of a desk so they

| Electric Force Lab (3.A.2) Guide |  |  |
| :---: | :---: | :---: |
| Table of Contents, Title/Date, Detailed <br> Synopsis, Two Purposes | $/ 2$ |  |
| Mission 1: | Tidy Organized Table | $/ 1$ |
|  | Labeled Table | $/ 1$ |
|  | Complete Table | $/ 2$ |
| Mission 2: | FBD - Balloon 1 | $/ 3$ |
|  | FBD - Balloon 2 | $/ 3$ |
| Analysis 1: Electric Force Calc. | $/ 4$ |  |
| Question 1: Difficulties with data. | $/ 2$ |  |
| Question 2: Invalid assumptions made. | $/ 2$ |  |
| Work Not Shown Fee: |  | $-1-2-$ |
| Late Lab Fee: |  | -4 |
| Total: |  | /20 | don't interact with surrounding materials by polarization. Charge your two balloons by rubbing them with the material, and watch what they do. Measure their separation as best as you can without altering their position, then use trigonometry to determine their angles with respect to the vertical.

## Mission 2:

Make free body diagrams of both of the balloons, labeling all forces, and decomposing forces not in alignment with the x and y axes. In other words, all numeric values present should be on these diagrams.

## Analysis: 4 Points

1. Determine the electric force acting on the balloons, showing all work.

## Questions: 2 Points Each

1. What difficulties did you encounter in the gathering of data, and data analysis for this lab?
2. How would your assumptions made for your calculations differ if the balloons are of significantly different masses, inflation amounts, or had vastly different charges on them?

| AP Physics 2 | Unit 3.A - Electric Charge \& Force |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Application Problems, AP Test Preparation Questions |  |  |  |  |  |
| Presentation <br> Points: | $I 5$ | Late Fee: | -2 | Completion <br> (Booklet Check) | $I 5$ |

Your grade on this problem set will depend on the presentation you provide for your problems, and whether they are complete when you submit your Booklet at the end of the Unit.

1. Explain how charging by friction, conduction, induction, and polarization work.
2. How many electrons will it take to make $2.5 \mathrm{E}-5 \mathrm{C}$ of negative charge?
3. Two charges are put near each other. One's charge is $-4 q$, and the other is $+6 q$. Map the electric field that surrounds the two charges.
4. What is the electric field strength between two parallel plates with areas of $0.13 \mathrm{~m}^{2}$, and a charge of $1.4 \mathrm{E}-9 \mathrm{C}$ on the negative plate?
5. What is the electric force exerted between a charge of 4.2 E -8 C and -5.4 E-7 C, separated by a distance of 4.2 mm ? Is it attractive or repulsive?
6. How many electrons would have to be placed on a $4.6 \mathrm{E}-12 \mathrm{~kg}$ object to make it hover in an electric field of $4.5 \mathrm{E}-3 \mathrm{~N} / \mathrm{C}$ between two parallel plates?

## Unit 3.A Practice AP Multiple Choice Questions

The following problems (multiple choice and free response) are designed to train you to take the AP Physics 1 test in the spring, and will be scored at the end of the Unit - based on completion and accuracy.

1. If the distance between two positive point charges is tripled, then the strength of the electrostatic repulsion between them will decrease by a factor of
a. 3
b. 6
c. 8
d. 9
e. 12
2. Two 1 kg spheres each carry a charge of magnitude 1 C . How does $\mathrm{F}_{\mathrm{E}}$, the strength of the electric force between the spheres, compare to $\mathrm{F}_{\mathrm{G}}$, the strength of their gravitational force?
a. $\mathrm{F}_{\mathrm{E}}<\mathrm{F}_{\mathrm{G}}$
b. $F_{E}=F_{G}$
c. $F_{E}>F_{G}$
d. If the charges on the spheres are of the same sign, then $F_{E}>F_{G}$; but if the charges on the spheres are of opposite sign, then $\mathrm{F}_{\mathrm{E}}<\mathrm{F}_{\mathrm{G}}$.
e. Cannot be determined without knowing the distance between the spheres.
3. The figure shows three positive point charges. If the net electric force on the center charge is zero, what is the value of $y / x$ ?

a. $4 / 9$
b. $\sqrt{ }(2 / 3)$
c. $\sqrt{ }(3 / 2)$
d. $3 / 2$
e. $9 / 4$
4. The figure shows two point charges, +Q and -Q . If the negative charge were absent, the electric field at Point P due to +Q would have strength $E$. With -Q
 in place, what is the strength of the total electric field at $P$, which lies at the midpoint of the line segment joining the charges?
a. 0
b. E/4
c. $\mathrm{E} / 2$
d. E
e. 2E
5. A sphere of charge $+Q$ is fixed in position. A smaller sphere of charge $+q$ is placed near the larger sphere and released from rest. The small sphere will move away from the large sphere with
a. Decreasing velocity and decreasing acceleration
b. Decreasing velocity and increasing acceleration
c. Decreasing velocity and constant acceleration
d. Increasing velocity and decreasing acceleration
e. Increasing velocity and increasing acceleration
6. An object of charge +q feels an electric force $\mathbf{F}_{\mathrm{E}}$ when placed at a particular location in an electric field, $\mathbf{E}$. Therefore, if an object of charge $-2 q$ were placed at the same location where the first charge was, it would feel and electric force of
a. $-\mathbf{F}_{\mathrm{E} / 2}$
b. $-2 \mathbf{F}_{\mathrm{E}}$
c. $-2 q \mathbf{F}_{\mathrm{E}}$
d. $-2 \mathbf{F}_{\mathrm{E}} / \mathrm{q}$
e. $-\mathbf{F}_{\mathrm{E}} / 2 \mathrm{q}$
7. A charge of $-3 Q$ is transferred to a solid metal sphere of radius $r$. Where will this excess charge reside?
a. -Q at the center, and -2 Q on the outer surface
b. -2 Q at the center, and -Q on the outer surface
c. -3 Q at the center
d. $-3 Q$ on the outer surface
e. -Q at the center, -Q in a ring of radius $1 / 2 \mathrm{r}$, and -Q on the outer surface

## Unit 3.A Example AP Question - Free Response



Two point charges, $q_{1}$ and $q_{2}$, are placed 0.30 m apart on the x-axis, as shown in the figure above.
Charge $q_{1}$ has a value of $-3.0 \times 10^{-9} \mathrm{C}$. The net electric field at point $P$ is zero.
(a) What is the sign of charge $q_{2}$ ?

Positive $\qquad$ Negative
Justify your answer
(b) Calculate the magnitude of charge $q_{2}$.
(c) Calculate the magnitude of the electric force on $q_{2}$ and indicate its direction.
(d) Determine the $x$-coordinate of the point on the line between the two charges at which the electric potential (voltage) is zero.
(e) How much work is done by an external force to bring an electron from infinity to the point at which the electric potential (voltage) is zero? Explain your reasoning.

| AP Physics 2 | Unit 3.A Review - Electric Charges, Forces, Fields |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Points: | $I 14$ | Late or <br> Incomplete Fee: | $-2-4-6$ | Correction <br> Credit: | Final <br> Score: |  |

Solve these problems here, THEN enter your responses in the bubble sheet provided. Each question is worth two points.

1. How many electrons have been removed from an object with a charge of +1.23 nC (nanocoulombs)?
A) 1.60 E 9 electrons
B) 6.55 E 9 electrons
C) 7.68 E 9 electrons
D) 9.80 E 9 electrons
E) 4.8 E 9 electrons
2. What is the force between two objects separated by a distance of 2.1 cm , one with a charge of +1.2 E -6 C and one with a charge of $-2.3 \mathrm{E}-6 \mathrm{C}$ ?
A) -72 N
B) -56 N
C) 72 N
D) 56 N
E) 62 N
3. Consider two charges: one of $+1.2 \mathrm{E}-6 \mathrm{C}$ and one with a charge of $-2.3 \mathrm{E}-6 \mathrm{C}$ ? Will the two objects attract or repel each other?
A) Attract
B) Repel
C) Ignore
4. Find the electric field strength at a point 3.5 cm from a charge of $1.33 \mathrm{E}-5 \mathrm{C}$ ?
A) 5.55 E $7 \mathrm{~N} / \mathrm{C}$
B) 7.82 E $7 \mathrm{~N} / \mathrm{C}$
C) $9.76 \mathrm{E} 7 \mathrm{~N} / \mathrm{C}$
D) $8.26 \mathrm{E} 7 \mathrm{~N} / \mathrm{C}$
E) $6.24 \mathrm{E} 7 \mathrm{~N} / \mathrm{C}$
5. How far away from a point charge of $4.5 \mathrm{E}-8 \mathrm{C}$ will its field strength be $4.5 \mathrm{~N} / \mathrm{C}$ ?
A) 9.5 m
B) 4.5 m
C) 12.8 m
D) 135 cm
E) 1.96 m
6. What is the electric field strength between two parallel plates with equal areas of $1.3 \mathrm{E}-3 \mathrm{~m}^{2}$, and 7.5 E 5 electrons on the negative plate?
A) $2.3 \mathrm{~N} / \mathrm{C}$
B) $4.5 \mathrm{~N} / \mathrm{C}$
C) $6.8 \mathrm{~N} / \mathrm{C}$
D) 10.4 N/C
E) $11.8 \mathrm{~N} / \mathrm{C}$
7. Two point charges experience a force of repulsion equal to $3 \mathrm{E}-4 \mathrm{~N}$ when separated be 0.4 m . If one of the charges is $5 \mathrm{E}-4 \mathrm{C}$, what is the magnitude of the other charge?
A) $1.07 \mathrm{E}-11 \mathrm{C}$
B) $2.7 \mathrm{E}-11 \mathrm{C}$
C) $5.8 \mathrm{E}-9 \mathrm{C}$
D) $5.0 \mathrm{E}-4 \mathrm{C}$
E) $3.2 \mathrm{E}-9 \mathrm{C}$
