Name:_______________________

Electrostatics Test Review

25

Understanding the Electrostatic Equations

The electrostatic equation chart is capable of solving almost every electrostatic problem, if you understand it well.

q_1 causes E at a point a distance r from q_1. q_2 is a 2nd charge at point P.

	Potential	Potential Energy
SCALARS	$V = k_c \frac{q_1}{r}$ $\Delta V = -E\Delta d$ (gh [J/kg]) V (J/C)	$PE = k_c \frac{q_1 q_2}{r}$ $\Delta PE = -qE\Delta d$ (mgh [J]) J (Nm)
VECTORS	(g [N/kg]) N/C (V/m) $E = k_c \frac{\lvert q_1\rvert}{r^2}$ $= \frac{V}{\Delta d}$ Field	(mg [N]) N $F_e = k_c \frac{\lvert q_1 q_2\rvert}{r^2}$ $= qE$ Force

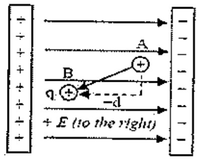
× r (× d) ↕ ÷ r (÷ d)

For multiple charges E is different for each charge, so you must x or ÷ by r for each individual charge (ie: $PE_{total} \neq F_{net}r$).

÷ q_2 ⟷ × q_2

q_2 is independent of the charges which cause E. So, for multiple charges you can x or ÷ F_{net} by q_2.

Non-k_c Equations

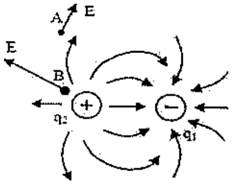


A parallel plate capacitor with two oppositely charged plates is an excellent example of a uniform electric field. E is constant in strength and direction everywhere between the plates and away from the edges. So the non-k_c equations should be used.

Notes: Since E is uniform, q will have the same F everywhere between the plates. d is negative since it is moved to the left. Q gains PE because a +q has moved closer to the + plate. When calculating $\Delta PE_{A \text{ to } B}$, d is the component parallel to E.

k_c Equations

Around point charges there is a non-uniform electric field. Notice that E has different strength and direction at points A and B. Therefore, you will have to use the k_c equations.



Calculating V at point A is simple, since V is a scalar:

$$V = k_c \frac{q_1}{r_1} + k_c \frac{q_2}{r_2}$$ where r_1 is the distance to q_1, etc.

Calculating F or PE would only be possible, of course, if there was a third charge at point A. Then:

$$F_{1on3} = k_c \frac{q_1 q_3}{r_1^2} \qquad F_{2on3} = k_c \frac{q_2 q_3}{r_2^2}$$ and vector addition would be necessary to find F_{net}.

A Gravity Analogy

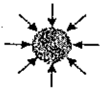
Gravity is the most commonly know field force and provides the easiest way to understand the electrostatic quantities. The equations are then easy to remember: g = E; m = q; h = d.

E is like g

The acceleration due to gravity, "g", is also known as the gravitational field. g is caused by mass (the earth). E is caused by charges, q.

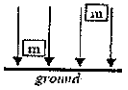
Near the earth g is constant: −9.8 m/s² like E is constant between a parallel plate capacitor

Far from the earth, g is not constant, like a point charge.



F_e is like mg

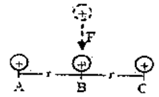
F_W = mg, which is the weight due to a mass put inside a constant g. Likewise, q_2 feels a force from the E created by q_1 (or the capacitor), so F_e = -qE.



Both m's have the same force of weight when g is constant. F_e is position independent, too, if E is constant (lines are ∥).

PE is like mgh

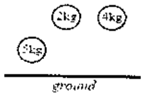
PE = mgh = -qEΔd. Remember that PE equals the work to move the object to that place and PE equals the amount of kinetic energy the object will have if released.



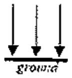
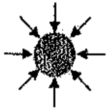
At B, F_e = E = 0, but PE ≠ 0 because it would take W to get it there. C doubles the PE given by A, since if released B feels 2 + q's pushing it away.

V (-Ed) is like gh

Think of gh as the gravitational potential for energy at a point (in J/kg). The gravitational potential for energy could be increased by increasing h or g (on Jupiter, for instance).



The 4 kg has more PE than the 2 kg, but they have the same potential (gh). The 2 kg has more potential than the 5 kg.

		Constant Field— (Field lines are parallel, like near the earth or near a charged flat plate) 		Point Sources (2 particles) Field lines radiate outward 	
		Gravitational (caused by mass)	Electric (caused by charge)	Gravitational (caused by mass)	Electric (caused by charge)
Vectors	Force (F)	$= mg$ (in N)	$= qE$ (in N)	$F_g = G\frac{m_1 m_2}{r^2}$ (in N)	$F_e = k_c \frac{q_1 q_2}{r^2}$ (in N)
	Field (potential for a force)	$= g$ (in N/kg)	$= E = \frac{V}{\Delta d}$ (in N/C)	$= G\frac{q_1}{r^2}$ (in N/kg)	$E = k_c \frac{q_1}{r^2}$ (in N/C)
Scalars	Potential Energy (PE or U)	$= mg\Delta h$ (in J) *h=0 on ground*	$\Delta PE = -qE\Delta d$ (in J)	$PE = G\frac{m_1 m_2}{r}$ (in J)	$PE = k_c \frac{q_1 q_2}{r}$ (in J)
	Potential (for energy) or Voltage	$= g\Delta h$ (in J/kg)	$\Delta V = -E\Delta d$ (in J/C)	$= G\frac{m_1}{r}$ (in J/kg)	$V = k_c \frac{q_1}{r}$ (in J/C)

Fill in the following blanks with the words **electrons** or **protons**.

Electrons are negatively charged and protons are positively charged. The protons reside in the nucleus of atoms and are tightly bound; they will never leave an atom as a result of electrostatic procedures. On the other hand, electrons are located outside the nucleus and are easily removed from or added to atoms. As an object begins to gain or lose electrons from its atoms, it becomes positively or negatively charged. A negatively charged object has more electrons than protons. A positively charged object has more protons than electrons.

Triboelectric Series
Celluloid
Sulfur
Rubber
Copper, Brass
Amber
Wood
Cotton
Human Skin
Silk
Cat Fur
Wool
Glass
Rabbit Fur

Use the triboelectric series to answer the following questions:

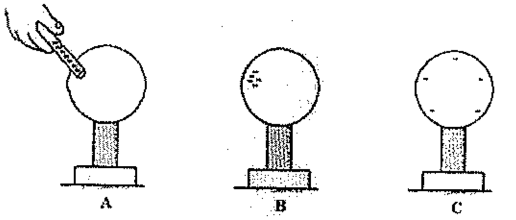
When you pull a **cotton** sweater off your **skin**, electrons are transferred from the skin (cotton, skin) to the cotton (cotton, skin). As a result, your body acquires a + (+ , -) charge and the cotton sweater acquires a − (+ , -) charge.

When you rub a **glass** rod with a **silk cloth**, electrons are transferred from the glass (glass, silk)to the Silk (glass, silk). As a result, the glass rod acquires a + (+ , -) charge and the silk cloth acquires a − (+ , -) charge.

Suppose you rub a rubber rod with a silk cloth and a second rubber rod with a wool sweater. The silk cloth will acquire a + (+ , -) charge; the wool sweater will acquire a − (+ , -) charge. The sweater and the cloth will then be observed to repel (attract, repel, not interact with) each other.

Suppose you rub a glass rod with a silk cloth and a second glass rod with rabbit fur. The silk cloth will acquire a − (+ , -) charge; the rabbit fur will acquire a + (+ , -) charge. The rabbit fur and the silk cloth will then be observed to attract (attract, repel, not interact with) each other.

Consider the conduction charging process described below:



A: A teacher holds a negatively charged metal bar by its insulating handle and touches it to a metal sphere (attached to an insulating stand).
B: The teacher pulls the metal bar away and the metal sphere acquires a charge.
C: The excess negative charge spreads uniformly about the surface of the metal sphere.

3. Diagram A is the charging step. How does the sphere become charged? Answer: b
   a. Electrons move from the insulating stand into the sphere.
   [✓ b.] Electrons move from the charged metal bar into the sphere.
   c. Protons move from the sphere into the negatively charged bar.

4. When the metal bar is pulled away in Diagram B, the metal bar is _____. Answer: C
   a. positively charged
   b. electrically neutral
   [✓ c.] still negatively charged, but has fewer excess electrons than it previously did.

5. Diagram C shows the excess negative charge distributed differently than it is in Diagram B. Explain why the excess negative charge would distribute itself as it does in Diagram C.
   The metal sphere is a conductor + allows the electors to move freely. The electrons spread evenly over the surface

$F = k\frac{q_1 q_2}{r^2}$

lteration in both the Quantity of Charge and the Distance

0.09N Two charged objects have a repulsive force of .080 N. If the charge of one of the objects is doubled, and the distance separating the objects is doubled, then what is the new force? $0.08N = k\frac{2q_1q_2}{2r^2}$

0.08N Two charged objects have a repulsive force of .080 N. If the charge of both of the objects is doubled and the distance separating the objects is doubled, then what is the new force? $0.08N = k\frac{2q_1 2q_2}{2r^2}$

0.08N Two charged objects have an attractive force of .080 N. If the charge of one of the objects is increased by a factor of four, and the distance separating the objects is doubled, then what is the new force? $0.08N = k\frac{4q_1q_2}{2r^2}$

0.027 N Two charged objects have an attractive force of .080 N. If the charge of one of the objects is tripled and the distance separating the objects is tripled, then what is the new force? $0.08N = k\frac{3q_1q_2}{3r^2}$ $\frac{0.08\times3}{(3)^2}$

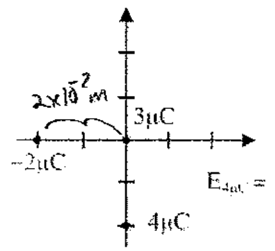
Use your understanding of electric force and electric field to fill in the following table. $E = F/q$

	Charge creating the E field (C)	Charge used to test the E field (C)	Force experienced by test charge (N)	Electric Field Intensity (N/C)	Distance (fictional units)
a.	4.0×10^{-4} C	1.0×10^{-6} C	0.20 N	2×10^{5} N/C	d
b.	4.0×10^{-4} C	2.0×10^{-6} C	0.4 N	2.0×10^{5} N/C	d
c.	8.0×10^{-4} C	1.0×10^{-6} C	0.40 N	4×10^{5} N/C	d
d.	8.0×10^{-4} C	2.0×10^{-6} C	0.8 N	4.0×10^{5} N/C	d
e.	8.0×10^{-4} C	1.5×10^{-6} C	0.60 N	4×10^{5} N/C	d
f.	8.0×10^{-4} C	1.0×10^{-6} C	0.10 N	1.0×10^{5} N/C	2d
g.	8.0×10^{-4} C	2.0×10^{-6} C	0.20 N	1×10^{5} N/C	2d
h.	8.0×10^{-4} C	1×10^{-6} C	0.10 N	1×10^{5} N/C	2d
i.	4.0×10^{-4} C	the answers can	vary provided	8.0×10^{5} N/C	0.5 d
j.	4.0×10^{-4} C	that the F/q	ratio stays the same	8×10^{5} N/C	0.5 d

Two fixed charges are placed on the x-y axis, as shown on the diagram. A third charge of 3μC is moved from infinity to the origin. Each line is 1 cm.

$E = k\frac{q}{(r)^2}$

$E_{-2\mu C}$ =



$E_{4\mu C}$ =

This is a good practice problem, but there will not be a question this hard on the test

A. Calculate the electric field due to each charge at the origin.

$E_{-2\mu C} = k\frac{-2\times10^{-6}C}{(2\times10^{-2}m)^2} = 4.5\times10^{7}$ N/C

$E_{4\mu C} = 9\times10^{7}$ N/C twice the q twice the E

B. Calculate the net electric field at the origin, both magnitude and direction.

$E_{net} = \sqrt{(E_{-2\mu C})^2 + (E_{4\mu C})^2}$

$E_{net} = 1\times10^{8}$ N/C

$\theta = \tan^{-1}(9/-4.5) = -63° + 180° = 117°$

C. Calculate the net force on the 3μC charge.

N/C · C = N, so, $F = qE = 1\times10^{8}$ N/C $\cdot 3\times10^{-6}$ C $= 300$ N

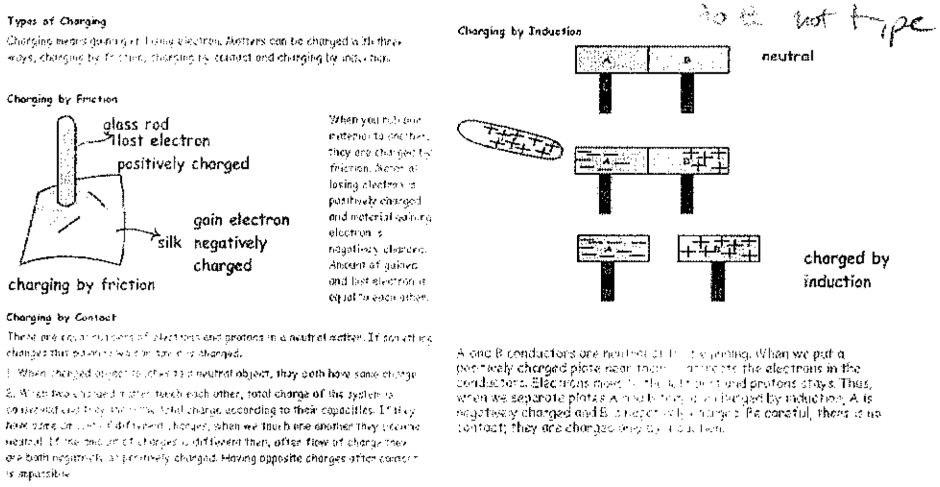
A balloon with a charge of 4.0×10^{-5} C is held a distance of 0.10 m from a second balloon having the same charge. Calculate the magnitude of the repulsive force. **PSYW**

$F = k\frac{q_1 q_2}{d^2} = 9\times10^{9}\frac{4\times10^{-5}C \cdot 4\times10^{-5}C}{(.10m)^2} = 1440N$

Calculate the electrical force (in Newtons) exerted between a 22-gram balloon with a charge of -2.6 μC and a wool sweater with a charge of +3.8 μC; the separation distance is 0.75 m. (NOTE: a μC or microCoulomb is a unit of charge; 10^6 μC = 1 C) PSYW

$9\times10^{9}\frac{2.6\times10^{-6}C \cdot 3.8\times10^{-6}C}{(.75m)^2} = 0.16N$

drop the + − signs becaus Q's refer to the not type



Types of Charging

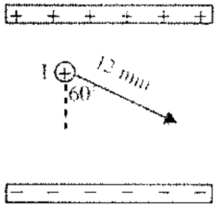
Charging means gaining or losing electron. Matters can be charged with three ways, charging by friction, charging by contact and charging by induction.

Charging by Friction

Charging by Contact

Charging by Induction

5. A +3C charge is moved in a uniform electric field that has a field strength of 500 N/C.



A. Calculate the distance it moves parallel to the field.
$d = .012m \cdot \cos 60° = .006m$

B. Which direction does the electric field point? Down

C. Calculate the ΔPE of the charge.
$\Delta PE = -qEd = -(3C) \cdot 500$ N/C $\cdot .006m = -9J$

D. Since electric field is also in V/m and the plates are separated by 18mm, calculate the voltage of the plates.
500 V/m · .018m = 9V

E. If this is a 6μF capacitor, how much charge is held on it?
6×10^{-6} C/V · 9V = 5.4×10^{-5} C