Name: Midterm 2 Solutions

ID: ______________________

Physics 203

Midterm Exam 2

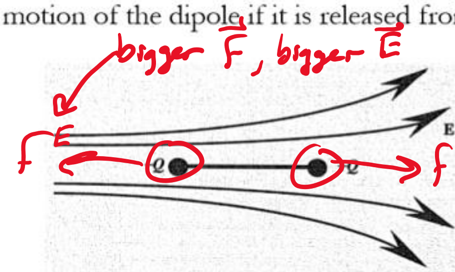
5/15/2024

Collaboration is not allowed. Allowed on your desk are: ten 8.5 x 11 inch doubled sided sheets of notes that are bound together, non-communicating graphing scientific calculator, 1 page of scratch paper, writing utensils, and the exam. You will have 80 minutes to complete this exam.

For questions 1 through 6 **fill in the square** next to all correct answers. A given problem may have more than one correct answer. Each correctly bubbled answer will receive two points. There are **7** correct answers in this section and only the first **7** filled in answers will be graded. There is no partial credit.

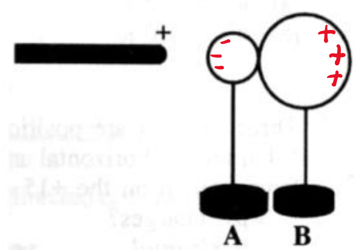
1. A rigid electric dipole is free to move in the non-uniform electric field represented in the figure. Which of the following phrases accurately describe the initial motion of the dipole if it is released from rest in the position shown?

   ☐ (a) It moves to the left.
   ☐ (b) It moves to the right.
   ☐ (c) It does not move at all.
   ☐ (d) It moves towards the top of the page.
   ☐ (e) It begins to rotate.



2. Two uncharged, conducting spheres, A and B, are held at rest on insulating stands and are in contact. Later, a positively charged rod is brought near sphere A as suggested in the figure. While the rod is in place, the two spheres are separated. How could the spheres be charged, if at all?

	Sphere A	Sphere B
☐ (a)	positive	positive
☐ (b)	positive	negative
☐ (c)	negative	positive
☐ (d)	negative	negative
☐ (e)	zero	zero



3. A wool sock is rubbed against your skin. Which one of the following statements is most likely.

   ☐ (a) The wool **gains protons** and your skin **loses electrons**.

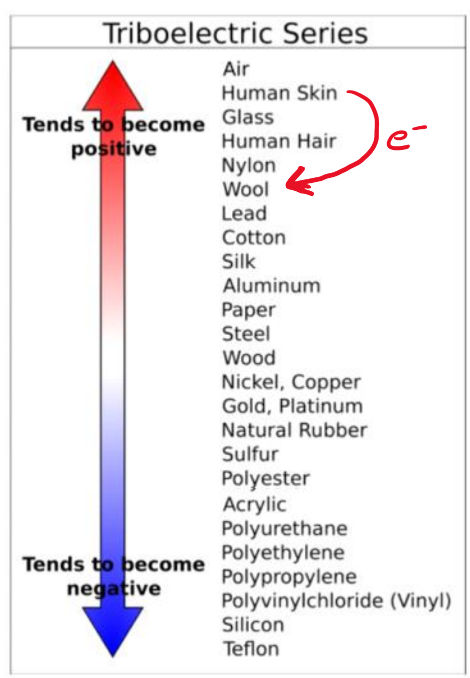
   ☐ (b) The wool **gains protons** and your skin **loses protons**.

   ☐ (c) The wool **gains electrons** and your skin **loses electrons**.

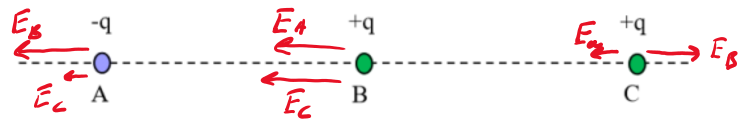
   ☐ (d) The wool **loses electrons** and your skin **loses electrons**.

   ☐ (e) The wool **loses electrons** and your skin **gains protons**.

   ☐ (f) The wool **gains protons** and your skin **gains protons**.

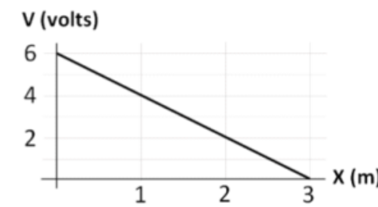


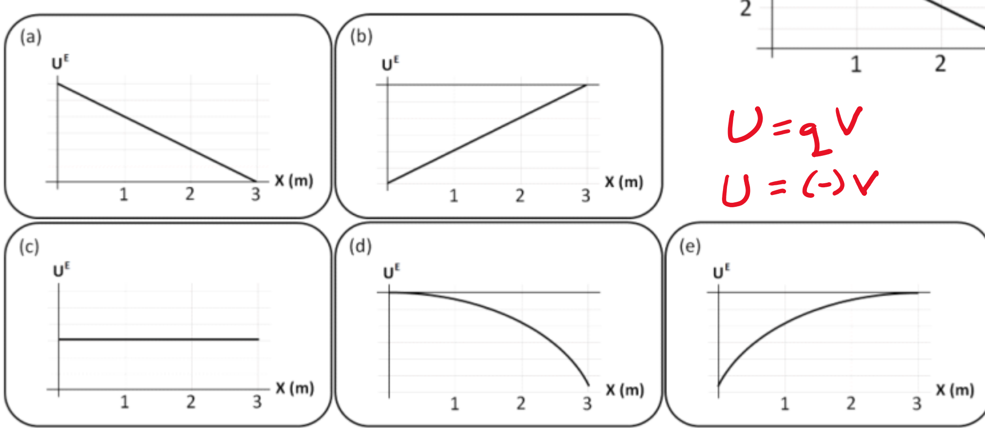
4. Consider the three equal magnitude electric charges shown below, separated by equal distances. Which of the following statements are true?



- ☐ (a) The net electric field at A, from charges B and C, is the largest magnitude of the three locations.
- ☑ (b) The net electric field at B, from charges A and C, is the largest magnitude of the three locations.
- ☐ (c) The net electric field at C, from charges A and B, is the largest magnitude of the three locations.
- ☑ (d) The net electric potential at A, from charges B and C, is the highest of the three locations. ← V = big + small
- ☐ (e) The net electric potential at B, from charges A and C, is the highest of the three locations. ← V = big − big
- ☐ (f) The net electric potential at C, from charges A and B, is the highest of the three locations. ← V = big − small

5. Pictured is a graph of the voltage along the x-axis for a region. Which of the following graphs could describe the electric potential energy of an electron in the same region?



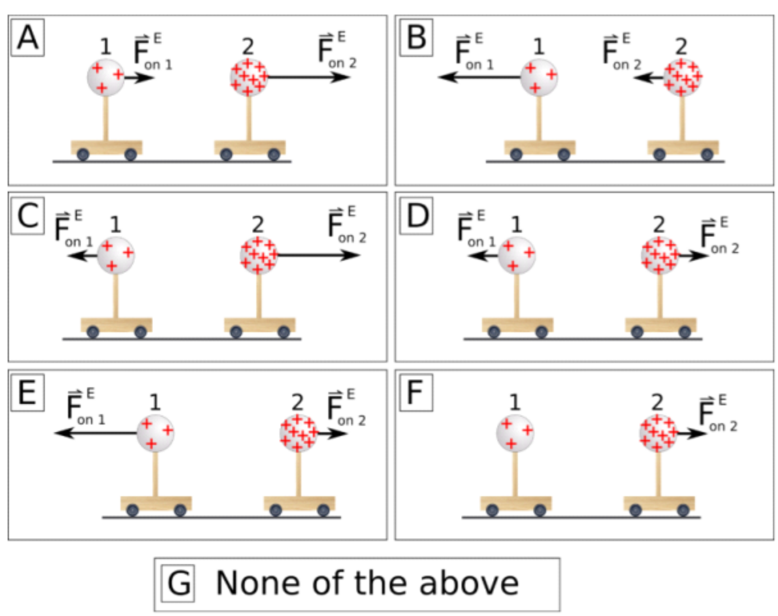


- ☐ (a)
- ☑ (b)
- ☐ (c)
- ☐ (d)
- ☐ (e)

$U = qV$

$U = (-)V$

6. Two uniformly charged spheres are firmly fastened to, but electrically insulated from, their bases. The net charge on sphere 2 is three times the net charge on sphere 1. Which physical representation correctly shows the magnitude and direction of the electric forces on each sphere?



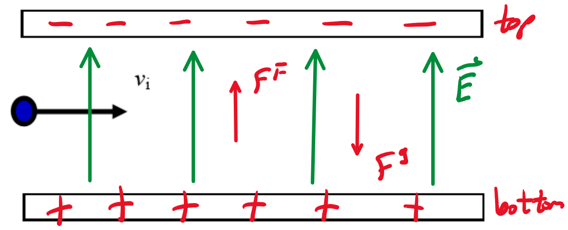
- ☐ (a)
- ☐ (b)
- ☐ (c)
- ☑ (d)
- ☐ (e)
- ☐ (f)
- ☐ (g)

Newton's 3rd

$F = k \frac{q_1 q_2}{|\Delta r_{12}|^2}$

both forces depend on q_1 & q_2! ⇒ equal forces

7. (11 points) You can find the mass of a test charge by shooting it horizontally in between a set of large parallel plates, as shown in the figure. The voltage (electric potential difference) between the plates can be adjusted so that the charged particle does not deflect from its original trajectory. A helium nucleus of charge **+2e** and mass **6.6 x 10^{-27} kg** is fired into such a parallel plate system. Assume a constant electric field between the plates.



(a) If the charge is not to deflect, what must be the sign of the charges on each of the plates - draw them on the plates in the figure.

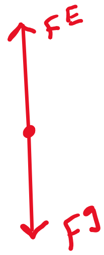
(b) Which plate is higher in electric potential?

(c) What magnitude electric field will prevent the helium nucleus from deflecting?

(d) If the electric potential difference between the plates were decreased, would you expect the particle to deflect up, down, or not at all? Explain.

(e) If the mass of the particle were reduced, with the original voltage difference and plate separation, would you expect the particle to deflect up, down, or not at all? Explain.

(a) FBD



$\Sigma F_y = 0 \Rightarrow a_y = 0 \Rightarrow$ no deflection

$\vec{F} = q\vec{E}$

$(\uparrow) = (+)(\uparrow) \Rightarrow E\uparrow$

(b) + charges create +V, negative charges create −V ⇒ bottom plate has higher V

(c) $\Sigma F_y = m a_y$ (see FBD above!)

$F^E + F^g = m a_y^{\,0}$ no deflection ⇒ $a_y = 0$

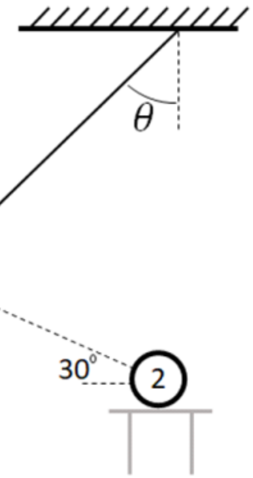
$q E_y - mg = 0$

$E_y = \frac{mg}{q} = \frac{(6.6\times10^{-27}\,kg)(9.8\,\frac{m}{s^2})}{(2)(1.6\times10^{-19}\,C)} = 2.0\times10^{-7}\,\frac{N}{C}$

(d) if ΔV decreases, the charges on each plate must be smaller ⇒ less $\vec{E}$ ⇒ smaller F^E ⇒ deflect downward b/c F^g is now stronger than F^E.

(e) m↓ ⇒ F^g is smaller ⇒ $|F^E| > |F^g|$ ⇒ deflect upwards towards top plate

7. (14 points) On Earth, a **0.3 kg** charged pith ball (labeled 1 in the diagram) is hanging from a string at an unknown angle of **θ** with respect to the vertical. A second charged pith ball (labeled 2 in the diagram) is fixed to a table such that it is **0.85 meters** away from the first ball. The line between the two balls makes an angle of **30 degrees** with respect to the horizontal. Both pith balls have identical **+5.8 μC** charges. The system is in equilibrium. Model the pith balls as point charges. Note, the figure is not drawn to scale and **θ** is not 30 degrees.

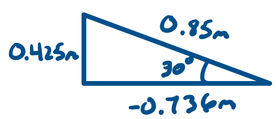


(a) What is the electric field created by the second charge at the location of the first charge? Using a standard coordinate system, express in cartesian components as **<E_x, E_y>**.

(b) Is this in stable or unstable equilibrium? Explain.

(c) What is the angle, **θ**, the string makes with the vertical?

(a) $\vec{E} = k \frac{q}{|\Delta \vec{r}|^2} \Delta\hat{r}$



$\Delta\vec{r} = \langle -0.736, 0.425 \rangle$ m

$|\Delta\vec{r}| = 0.85$ m

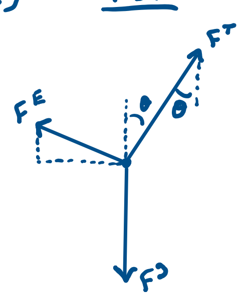
$\Delta\hat{r} = \langle -0.866, 0.5 \rangle$

$\Rightarrow \vec{E} = 72{,}250 \langle -0.866, 0.5 \rangle \frac{N}{C}$

$= \langle -62500, 36100 \rangle \frac{N}{C}$

(b) stable, if move ↖① , then F^E gets smaller ⇒ gravity moves it back to current location. If move ①↘ then F^E gets bigger ⇒ moves it back to current location. ⇒ stable equilib

(c) FBD



x

$F^E_x + F^T_x = m a_x^{\,0}$

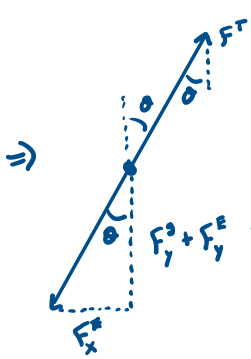
$\Rightarrow F^E_x = -F^T_x$

y

$F^g + F^E_y + F^T_y = m a_y^{\,0}$

$\Rightarrow F^g + F^E_y = -F^T_y$

⇒



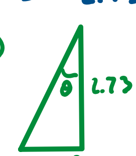
$F^g + F^E_y = -mg + qE_y = -(0.3)(9.8) + (5.8\times10^{-6})(36{,}100)$

$= -2.73$ N

$F^E_x = qE_x$

$= (5.8\times10^{-6})(-62500)$

$= 0.363$ N



$\Rightarrow \theta = \tan^{-1}\left(\frac{.363}{2.73}\right)$

$\theta = 7.56°$