Name: ____________________ ID: ____________ ~~Lab (~~day/time): ____________

Physics 203
Midterm Exam 2
5/16/2018

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

Constants:

$e = 1.602 \times 10^{-19} C$, $m_e = 9.109 \times 10^{-31} kg$, $m_p = 1.67 \times 10^{-27} kg$

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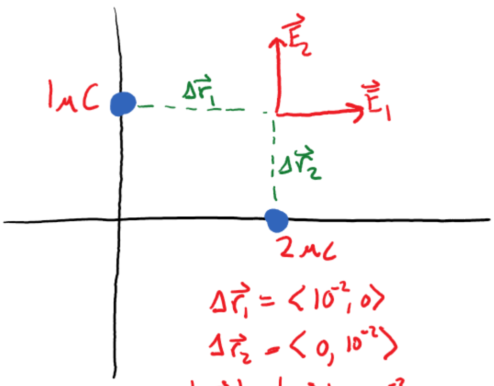
1. (6 points) One charge of 2 μC is placed at (x,y) = (1 *cm*, 0 *cm*), another charge of 1 μC is placed at (x,y) = (0 *cm*, 1 *cm*).

a) What is the electric field at (x,y) = (1 *cm*, 1 *cm*)?



$\Delta\vec{r}_1 = \langle 10^{-2}, 0\rangle$

$\Delta\vec{r}_2 = \langle 0, 10^{-2}\rangle$

$|\Delta\vec{r}_1| = |\Delta\vec{r}_2| = 10^{-2} m$

$\Delta\hat{r}_1 = \langle 1, 0\rangle$

$\Delta\hat{r}_2 = \langle 0, 1\rangle$

$E_1 = k \frac{q}{|\Delta r_1|^2} \Delta\hat{r}_1 = (9\times10^9) \frac{(10^{-6})}{10^{-4}} \langle 1, 0\rangle$

$E_1 = 9\times10^7 \langle 1, 0\rangle \frac{N}{C}$

$E_2 = 1.8\times10^8 \langle 0, 1\rangle \frac{N}{C}$

$\vec{E}_{tot} = \vec{E}_1 + \vec{E}_2 = \langle 9\times10^7, 0\rangle + \langle 0, 1.8\times10^8\rangle$

$\boxed{\vec{E}_{tot} = \langle 9\times10^7, 1.8\times10^8\rangle \frac{N}{C}}$

or $\vec{E}_{tot} = 9\sqrt{5}\times10^7 \frac{N}{C} \langle \frac{1}{\sqrt{5}}, \frac{2}{\sqrt{5}}\rangle$

b) What is the magnitude of the electric field?

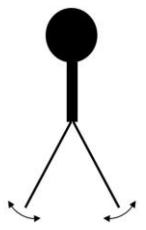
$|\vec{E}_{tot}| = \sqrt{(9\times10^7)^2 + (1.8\times10^8)^2}$

$= \sqrt{(9^2\times10^{14}) + (18^2\times10^{14})}$

$\boxed{|\vec{E}_{tot}| = 9\sqrt{5}\times10^7 \frac{N}{C} \quad = 20.1 \frac{N}{C}}$

For questions 2 through 5 **fill in the square** next to all correct answers, a given problem may have more or less than one correct answer. Each correctly chosen 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.

A metal rod with an excess of positive charge touches a previously neutral electroscope and the leaves spread apart. The metal rod is then removed. Which of the following options will cause the leaves to move closer together?



a) Bringing a negatively charged metal rod close to the top of the electroscope

b) Bringing a positively charged metal rod close to the top of the electroscope

c) Bringing a negatively charged insulating rod close to the top of the electroscope

d) Bringing a positively charged insulating rod close to the top of the electroscope

2. A +1 C charge is placed at the origin. A -2 C charge is placed on the x-axis, 30 cm to the right of the origin. Which of the following statements are true?

a) Other than $x = \pm\infty$, there are no locations on the x axis where the electric field magnitude is zero.

b) Other than $x = \pm\infty$, there is only one location on the x axis where the electric field magnitude is zero.

c) In addition to $x = \pm\infty$, there is more than one location on the x axis where the electric field magnitude is zero.

d) The electric field is zero at a point between the two charges.

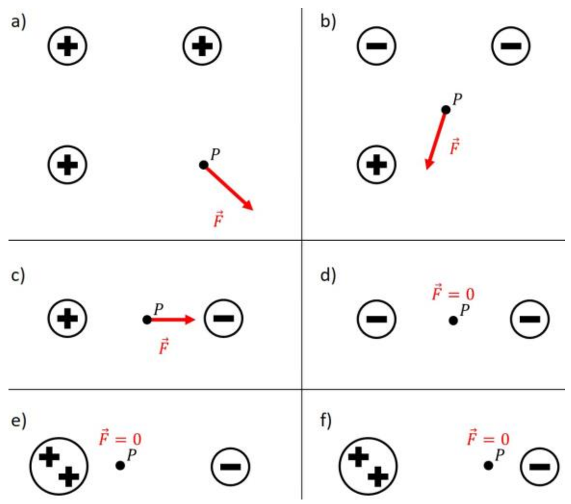
e) Other than $x = -\infty$, the electric field is zero at one point to the left of both charges.

f) Other than $x = \infty$, the electric field is zero at one point to the right of both charges.

g) The electric potential energy of the -2 C charge is greater than the electric potential energy of the +1 C charge.

4. Which of the following situations correctly depict the force on a negative charge placed at the black dot? (+ and - charges have equal magnitudes, ++ implies twice the charge)

a)
b)
c)
d)
e)
f)



5. For the electric force to do no work on a charge moving through an electric field, the charge must be:

a) Moving along an electric field line, in the direction of the electric field

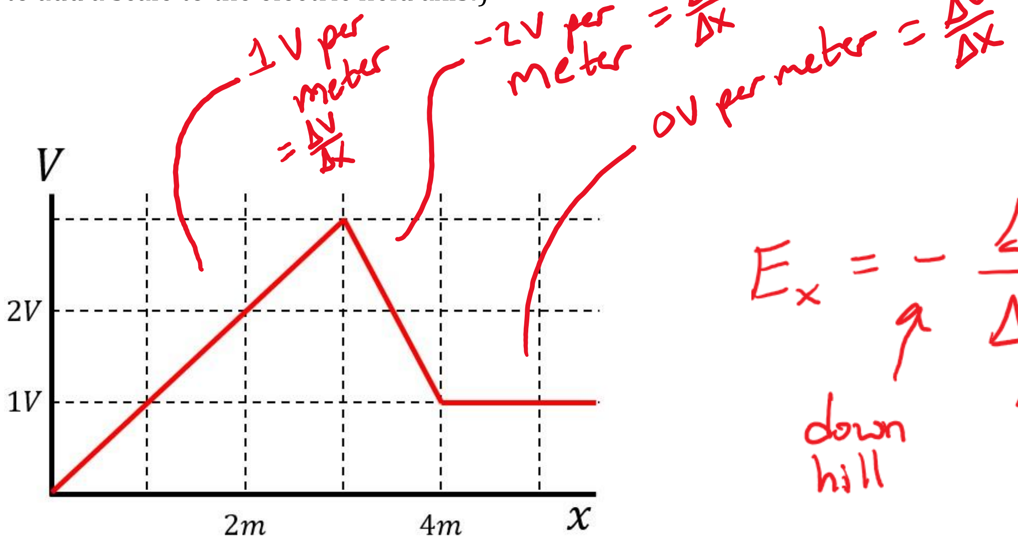
b) Moving along an electric field line, opposite the direction of the electric field

c) Moving along an equipotential line

d) Moving along an electric potential vector line

e) Moving along an electric potential energy vector line

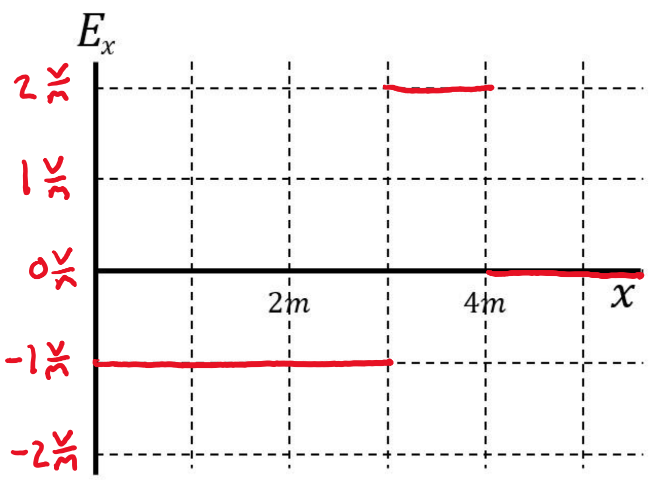
6. **(5 points)** The electric potential along the x-axis is given by the following plot. Create a graph of the x component of the electric field along the same x-axis. (Make sure to add a scale to the electric field axis!)



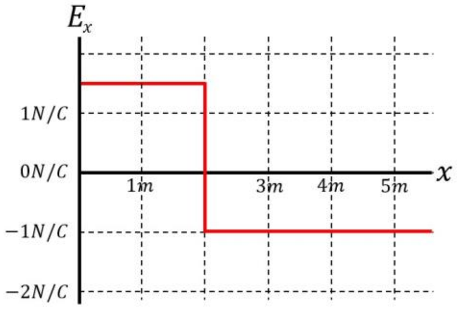
$$E_x = -\frac{\Delta V}{\Delta x}$$

down hill

slope



7. **(10 points)** An electric field points only in the x direction (no y or z components). The x component is shown in the following graph. The potential energy of a **2 C** charge is **U = 10 J** at x = 0 m.



$U = qV$

$U(0) = 10J \Rightarrow V(0) = 5V$

a) (8 points) If the charge starts from rest at the origin and experiences no outside forces, what will it's kinetic energy be at x = 4 meters?

$E_x = -\frac{\Delta V}{\Delta x} \Rightarrow \Delta V = -E_x \Delta x$

$V(0) = 5V$

$V(2) - V(0) = -(1.5)(2-0)$ (E_x, Δx)

$V(2) = 5V - 3V = 2V$

$V(4) - V(2) = -(-1)(4-2)$ (E_x, Δx)

$V(4) = 2V + 2V = 4V$

$\Rightarrow \Delta V_{tot} = 4V - 5V = -1V$

$\Delta U = q\Delta V = (2)(-1) = -2J$

$\Delta KE = -\Delta U = +2J$

$KE = 0J$

$KE(4m) - KE(0m) = +2J$

$\boxed{KE(x=4m) = 2J}$

b) (2 points) What is the potential energy of the charge at x = 2 meters? (hint: this is the easy way to solve part a!)

$V(x=2m) = 2V$

$U(x=2m) = qV = 2(2V) = \boxed{4J}$

8. (8 points) Q1 is placed on the x axis at **x = -1.0 cm**. Q2 is placed on the x axis at **x = +1.0 cm**. For the following questions let the electric potential equal zero at $x = \pm\infty$.

a) Give a value for Q1 and a value for Q2 that will give $V = 0$ at the origin, but E 6= 0.

Q1: -1 nC

Q2: +1 nC

$Q_1 = -Q_2$

(−) q_1 · V=0 (+) q_2

$$V_{tot} = k\frac{-q}{\Delta r} + k\frac{+q}{\Delta r} = 0$$

b) Find the electric field vector at the origin for the charges you chose in part a.

These answers will depend on q_1, q_2

$$\vec{E}_1 = k\frac{q}{|\Delta\vec{r}|^2}\Delta\hat{r} = (9\times10^9)\frac{(-10^{-9})}{(10^{-2})^2}\langle 1,0\rangle = 9\times10^4\langle -1,0\rangle \frac{N}{C}$$

$$\vec{E}_2 = (9\times10^9)\frac{(+10^{-9})}{(10^{-2})^2}\langle -1,0\rangle = 9\times10^4\langle -1,0\rangle\frac{N}{C}$$

$$\vec{E}_{tot} = \vec{E}_1 + \vec{E}_2 = 1.8\times10^5\langle -1,0\rangle\frac{N}{C} \quad \text{or} \quad 1.8\times10^5\,\frac{N}{C} \text{ to the left}$$

c) Give a value for Q1 and a value for Q2 that will give $E = 0$ at the origin, but V 6= 0.

Q1: +1 nC

Q2: +1 nC

$Q_1 = Q_2$

(+) · (+)

$$\vec{E}_{tot} = \vec{E}_1 + \vec{E}_2 = 9\times10^4\langle 1,0\rangle + 9\times10^4\langle -1,0\rangle = 0$$

d) Find the electric potential at the origin for the charges you chose in part c.

$$V_{tot} = V_1 + V_2 = k\frac{q_1}{|\Delta\vec{r}|} + k\frac{q_2}{|\Delta\vec{r}|}$$

$$q_1 = q_2 \Rightarrow V_{tot} = 2k\frac{q}{|\Delta\vec{r}|} = 2(9\times10^9)\frac{(10^{-9})}{(.01)}$$

$$V_{tot} = 18\times100$$

$$V_{tot} = 1800\text{ V}$$

(for my choice of q_1, q_2)

9. (12 points) A ball with charge **q = -2.3 C** and mass **m = 0.85 kg** is falling due to gravity. A uniform vertical electric field of strength **E = 5.3 N/C** exists between the ground and **D** meters above the ground. The ball enters the electric field from the top with a downward velocity $\sim\mathbf{v}_i$ **= 5.0 m/s** and hits the ground with a downward velocity $\sim\mathbf{v}_f$ **= 4.0 m/s**.

a) (2 point) What direction does the electric field point?

$v_f < v_i \Rightarrow \vec{F}_g \downarrow,\ \vec{F}_E \uparrow$; $q<0$ $\Big\}$ $\vec{F} = (-2.3)\vec{E} \Rightarrow$ **$\vec{E}$ points $\downarrow$**

b) (8 pts) What is the distance **D**?

$$W_{Elec} = E_f - E_i$$

$$|\vec{F}_E||D|\cos\theta = \frac{1}{2}mv_f^2 - \left(\frac{1}{2}mv_i^2 + mgD\right)$$

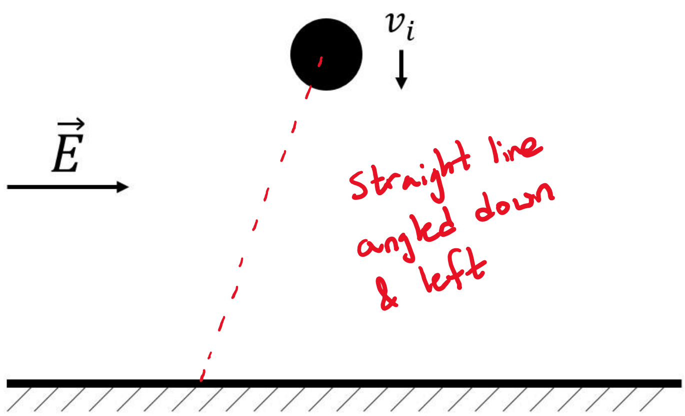
$$-|q||E|D = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 - mgD$$

$$mgD - |q||E|D = \frac{1}{2}m(v_f^2 - v_i^2)$$

$$D(mg - |q||E|) = \frac{1}{2}m(v_f^2 - v_i^2)$$

$$D = \frac{\frac{1}{2}m(v_f^2 - v_i^2)}{mg - |q||E|} = \frac{\frac{1}{2}(0.85)(4^2 - 5^2)}{(0.85)(9.8) - (2.3)(5.3)} = \boxed{0.99\ m}$$

c) (2 pts) The same situation occurs, except the uniform electric field of strength **E** now points horizontally to the right. Sketch the path of the ball as it falls through the electric field.



$\vec{E} \rightarrow$; $\vec{F}_E = q\vec{E}$; $q<0$ $\Big\}$ $\vec{F}_E$ is to the left

$\vec{F}_E = q\vec{E}$; $\vec{F}_G = -mg\,\hat{y}$ $\Big\}$ both are const $\Rightarrow \vec{F}_{net} = \text{const} \Rightarrow \vec{a} = \text{const}$