Name: ______________________ ID: ________________ Lab (day/time): ____________

Physics 203
Midterm Exam 2
5/15/2019

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, 10 pages of scratch paper, writing utensils, a ruler, and the exam. You will have 80 minutes to complete this exam.

Constants:

$$\mathbf{k = 8.99 \times 10^{9}\ N\ \frac{m^2}{C^2}}, \quad \mathbf{e = 1.602 \times 10^{-19}\ C},$$

$$\mathbf{m_p = 1.67 \times 10^{-27}\ kg}, \quad \mathbf{m_e = 9.109 \times 10^{-31}\ kg}$$

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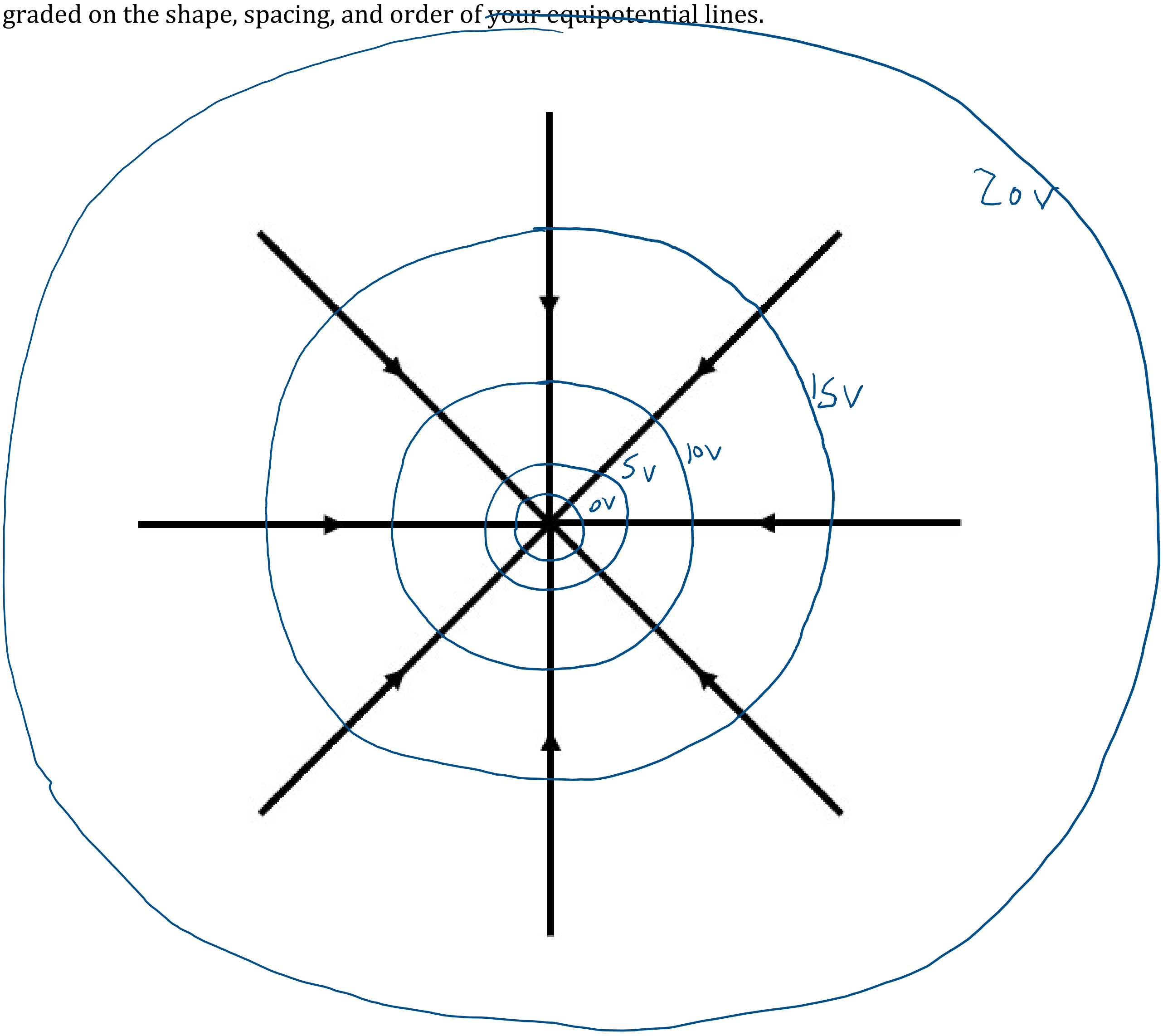
1. (3 points) On top of the following plot of **Electric Field Lines**, draw appropriate **Equipotential Lines** for values of **0 V, 5 V, 10 V, 15 V, and 20 V**. Your drawing should be internally consistent such that it could be possible. *Make sure to label your equipotential lines!* Be as neat as you can. You will be graded on the shape, spacing, and order of your equipotential lines.



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 **10 correct answers** in this section and only the first **10** filled in answers will be graded. There is no partial credit.

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2. Which of the following quantities are scalars?

a) Electric Field

b) Charge

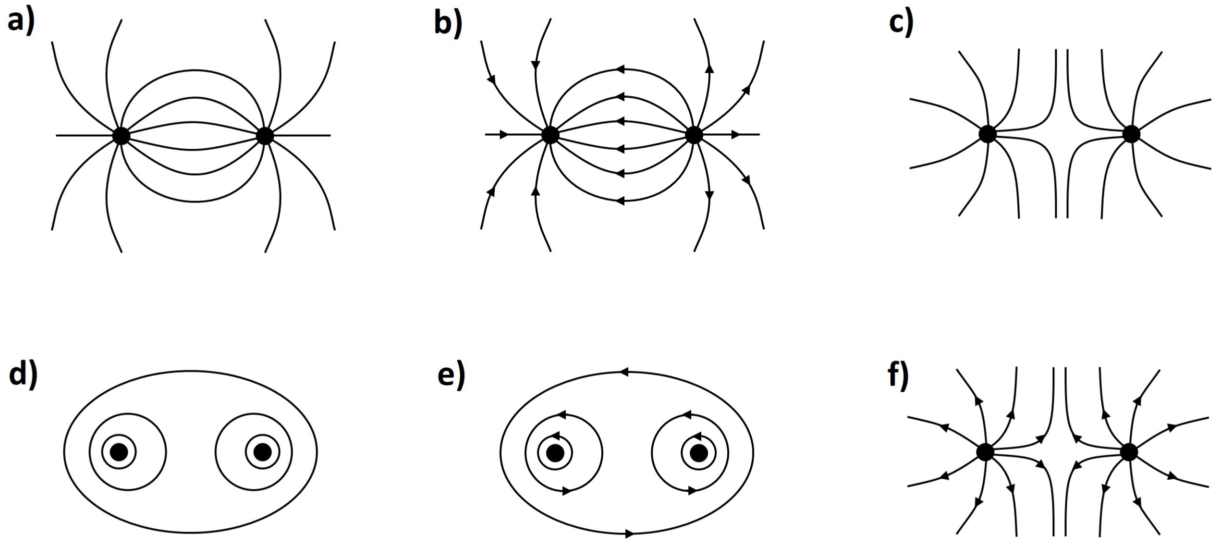
c) Electric Force

d) A proton's velocity

e) Electric Potential

f) Electric Potential Energy

For questions 3 and 4, refer to the figures below.



3. Which of the figures could represent electric fields?

a)

b)

c)

d) e)

f)

4. Which of the figures could represent electric potential fields?

a)

b)

c)

d)

e)

f)

5. Which of the following statements are true?

a) Excess charge on an insulator will move to the surface.

b) An electron in an electric potential will move towards a location where it has more electric potential energy (assume no other forces).

c) In a static situation, electric fields will be parallel to the surface of a conductor.

d) Positive charges are attracted to negative charges.

e) It is possible to polarize both conductors and insulators.

f) Most metals are conductors.

g) In a static situation, the electric field will always be zero inside a conductor.

h) In a static situation, the electric potential will always be zero inside a conductor.

i) In a static situation, the electric field will always be a non-zero constant inside a conductor.

j) In a static situation, the electric potential will always be a constant inside a conductor.

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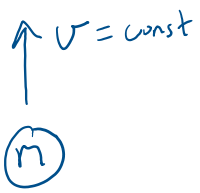
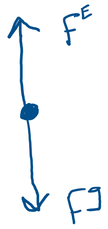
6. **(5 points)** A 10 gram mass is given a charge of -3 μC and placed in a uniform electric field. Holding the mass in your hand, you give it a quick push upwards and pull your hand away so that it no longer is touching the mass. After you are no longer touching the mass, it continues vertically upwards at a constant velocity of 2.3 m/s.

What is the strength and direction of the uniform electric field which could accomplish this?



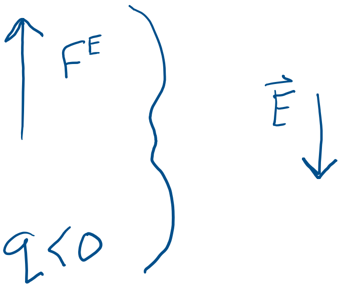
FBD



$$F_{net} = 0 = F^E + F^g = qE - mg$$

$$\Rightarrow E = \frac{m}{q} g$$

$$= \frac{0.01\ \text{kg}}{3 \times 10^{-6}\ \text{C}} 9.8\ \text{m/s}^2 = 3.2 \times 10^4\ \frac{\text{N}}{\text{C}}$$



$$\vec{E} = 32{,}000\ \frac{\text{N}}{\text{C}}\ \text{down}$$

7. **(6 points)** Mr. Musk's car is floating through space unaffected by anything other than an electric field. Starting at an electric potential of 10 V, it moves to a new electric potential of 900 V. You notice that it starts at a speed of 100 m/s and is moving at 101 m/s at the new location. The mass of the car is 1000 kg.

How much excess charge is the car carrying, and is it positive or negative?

$$10\,V \rightarrow 900\,V \Rightarrow \Delta V = +890\,V$$

$$\Delta KE + \Delta U^E = 0$$

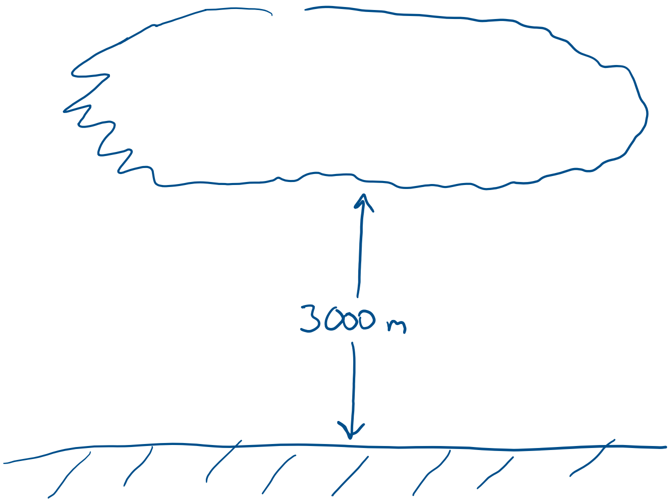
$$\Rightarrow \Delta KE = -\Delta U^E$$

$$\Rightarrow \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = -q\Delta V$$

$$\Rightarrow q = \frac{1}{2}\frac{m}{\Delta V}(v_i - v_f)^2 = \boxed{-113\,C}$$

8. **(4 points)** Air is typically an insulator. But when exposed to a strong enough electric field, the electrons can strip away from the nuclei and the air becomes a conducting plasma. This happens when it is subjected to electric fields in excess of 3 *kV/mm* such as during a lightning strike. A typical cumulonimbus cloud is formed 3 *km* above the earth's surface. We can model the cloud and the Earth's surface as large charged parallel plates.

Find the magnitude of the electric potential difference between the Earth's surface and a cloud needed to create a lightning strike.



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

$$3\,\frac{kV}{mm} = 3000\,\frac{V}{mm}\left(\frac{1000\,mm}{1\,m}\right) = 3\times10^6\,\frac{V}{m}$$

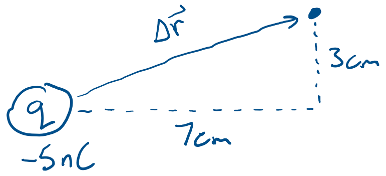
$$\Rightarrow \Delta V = -E\Delta x$$

$$|\Delta V| = \left(3\times10^6\,\frac{V}{m}\right)(3000\,m)$$

$$\boxed{\Delta V = 9\times10^9\,V}$$

9. **(6 points)** A charge of -5 nC is placed 7 cm in the negative x direction and 3 cm in the negative y direction from a kitten. (hint: draw a picture!)

a) What is the electric field that the kitten experiences? Answer in vector notation.



$\Delta\vec{r} = \langle 0.07, 0.03 \rangle$ m

$|\Delta\vec{r}| = \sqrt{(.07)^2 + (.03)^2}$

$= \sqrt{0.0058} = 0.0762$

$\hat{\Delta r} = \left\langle \frac{0.07}{0.0762}, \frac{0.03}{0.0762} \right\rangle$

$\vec{E} = k\frac{q}{|\Delta\vec{r}|^2}\hat{\Delta r} = -7759 \langle 0.92, 0.39 \rangle$ N/C

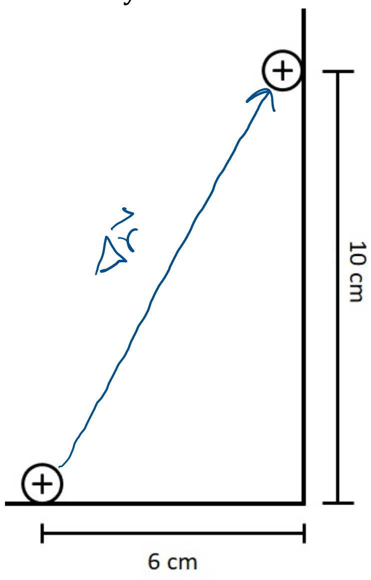
or

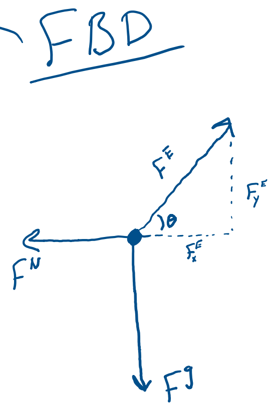
$\langle -7138, -3026 \rangle$ N/C

or equivalent

10. (9 points) One small sphere of mass 300 g and unknown amount of positive charge is fixed in place. Another *identical* sphere is suspended in place against a wall by the first sphere as shown (i.e. it is not glued or fixed to the wall). The first sphere is 6 cm from the wall and the suspended sphere is 10 cm above the ground.

How many electrons are each of the spheres missing? (hint: they are identical)





$F_y^E = |F^E|\sin\theta$ $\quad$ $|F^E| = k\frac{q^2}{|\Delta\vec{r}|^2}$

$F_y^E = F^g$ $\quad$ $\sin\theta = \frac{0.1}{\sqrt{.1^2 + .06^2}} = 0.857$

$\Rightarrow mg = k\frac{q^2}{|\Delta\vec{r}|^2}\sin\theta$

$\Rightarrow q^2 = \frac{mg|\Delta\vec{r}|^2}{k\sin\theta}$

$\Rightarrow q = 2.28\times10^{-6}\ C$

$|\Delta\vec{r}| = \sqrt{(0.1)^2 + (0.06)^2}$

$= 0.117\ m$

$\#e^-_{missing} = \frac{2.28\times10^{-6}\ C}{1.602\times10^{-19}\ C/e^-}$

$\Rightarrow \#e^-_{missing} = 1.42\times10^{13}$ electrons missing