Name:______________________________

ID:______________________________

Physics 203

Midterm Exam 2

5/11/2022

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.

Constants

$m_{proton} = 1.67 \times 10^{-27}$ kg

$m_{electron} = 9.11 \times 10^{-31}$ kg

$e = 1.60 \times 10^{-19}$ C

$k = 8.99 \times 10^{9}$ N m^2/C^2

For questions 1 through 3 **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 **4** correct answers in this section and only the first **4** filled in answers will be graded. There is no partial credit.

1. If the conditions are right (or wrong?) you can experience an electrostatic shock after getting out of a car when going to touch the metal door of the car. The car, seat, your cloths, and your skin are all initially net neutral. When you get out of the car, your clothes rub against the seat transferring charge between your cloths and the seat. Your clothes are in contact with your skin, so the net charge your clothes picked up is transferred to the skin on your back. Even though your clothes, and thus skin, transfer charge with the seat near your **back** you still get a shock when your **fingers** touch the metal door of the car. Which of the following statements must be true regarding these facts?

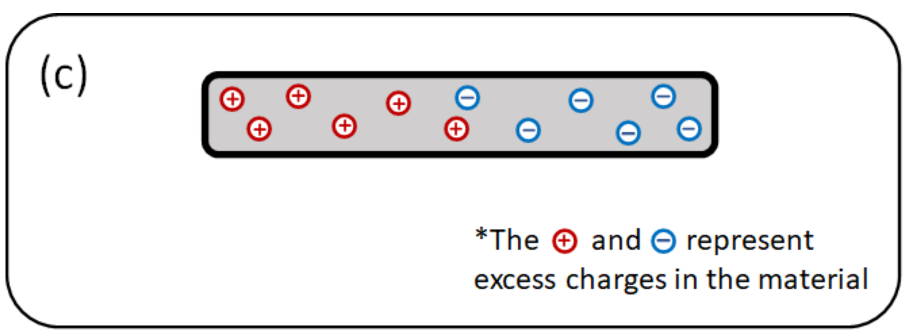
   □ (a) Your skin can act like an insulator.
   x (b) Your skin can act like a conductor.
   □ (c) Your skin creates charge out of nowhere.
   □ (d) Your skin acts like plastic.

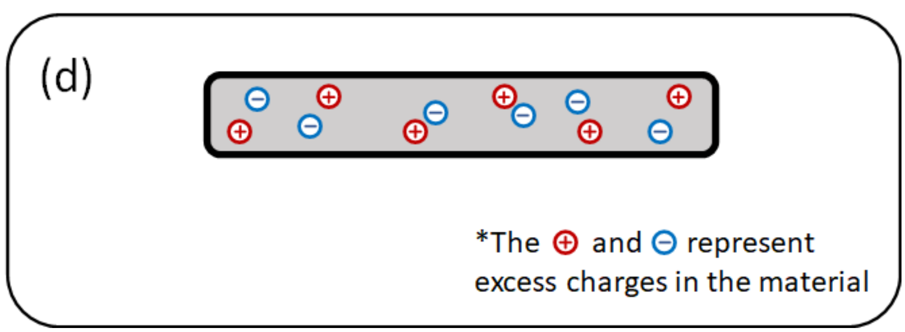
2. Which of the following statements are true about a scenario where you get an electrostatic shock from a metal object?

   □ (a) Protons transfer between you and the metal, resulting in the shock.
   □ (b) Neutrons transfer between you and the metal, resulting in the shock.
   x (c) Electrons transfer between you and the metal, resulting in the shock.
   □ (d) Speed force particles transfer between you and the metal, resulting in the shock and probably superpowers too.

3. Which of the following written descriptions and/or pictures represent a polarized system?

   □ (a) A PVC (polyvinyl chloride) pipe has excess electrons uniformly distributed on it after being rubbed against fur. The PVC pipe is far from other objects.
   x (b) A net neutral wooden board when a charged PVC (polyvinyl chloride) pipe is placed near, but does not touch, the wooden board.
   x (c) Image (c).
   □ (d) Image (d).



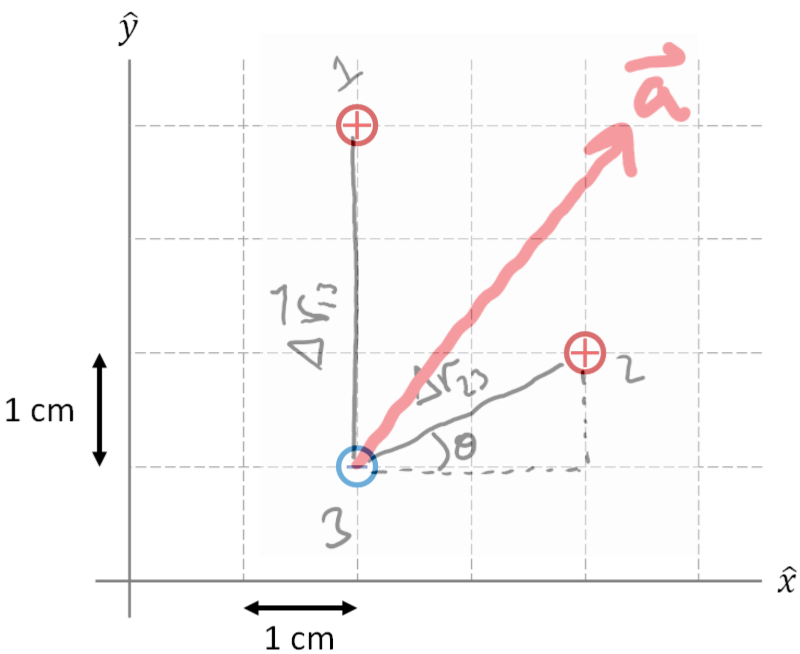


4. (7 points) Two positive charges and one negative charge of magnitude 1 μC each are arranged as shown, far from other objects.

   (a) What is the magnitude of the net force on the negative charge?

   (b) The positive charges are fixed in place, and the negative charge is allowed to move, starting from rest in its pictured location. Carefully draw a clearly labeled vector on the diagram that could represent the direction of the initial acceleration of the negative charge. Precise calculation is not necessary.

   (c) Will the magnitude of the acceleration of the negative charge increase, decrease, or remain constant in the first few moments after it begins to move? Explain using words, diagrams, algebra, etc.



a) $|\Delta\vec{r}_{13}| = 3\,cm = 0.03\,m$

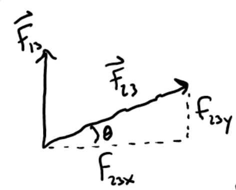
$|\Delta\vec{r}_{23}| = \sqrt{2_{cm}^2 + 1_{cm}^2} = \sqrt{5}\,cm$

$= 2.236\,cm = 0.02236\,m$

$|\vec{F}_{13}| = k\dfrac{q_1 q_3}{|\Delta\vec{r}_{13}|^2} = 9.99\,N$

$|\vec{F}_{23}| = k\dfrac{q_2 q_3}{|\Delta\vec{r}_{23}|^2} = 17.98\,N$

vector addition



$\theta = \tan^{-1}\left(\frac{1}{2}\right)$

$\theta = 26.57°$

$F_{13x} = 0$

$F_{13y} = |\vec{F}_{13}|$

$= 9.99N$

$F_{23y} = |\vec{F}_{23}|\sin\theta$

$= 8.041\,N$

$F_{23x} = |\vec{F}_{23}|\cos\theta$

$= 16.08\,N$

$\Rightarrow \vec{F}_{net} = \langle F_{23x}, F_{23y} + F_{13y} \rangle$

$= \langle 16.1, 18.0 \rangle\,N$

$\Rightarrow$ **$|\vec{F}_{net}| = 24.2\,N$**

b) See diagram ↗

$\vec{F}_{net} = m\vec{a}$, so $\hat{a} = \hat{F}_{net}$

c) because the negative charge is initially getting closer to the + charges, the F_{net} will be increasing $\left(|F| = k\dfrac{qq}{|\Delta r|^2}\right)$ (↑ $|F|$, ↓ $|\Delta r|^2$)

thus **$|\vec{a}|$ also increases**

Part (a) - 4 pts total

2 pts - high level individual force calculation - uses Coulomb's law or other appropriate physics to find the force (or E field) between two charges.

1 pts - mid level individual force calculation - mentions appropriate physics

1 pt - high level vector addition - uses vector addition to add forces (or E fields)

1 pt - Correct answer + units - (24.2 N)

0.5 pts - correct answer no units

Part (b) - 1 pt total

1 pt - high level vector representation - acceleration of negative charge is up and to the right, vector points somewhere between the two positive charges.

0.5 pts - mid level vector representation - acceleration of negative charge points exactly opposite of the appropriate direction

Part (c) - 2 pts total

2 pts - high level explanation - magnitude of acceleration is said to increase and explanation is complete and correct.

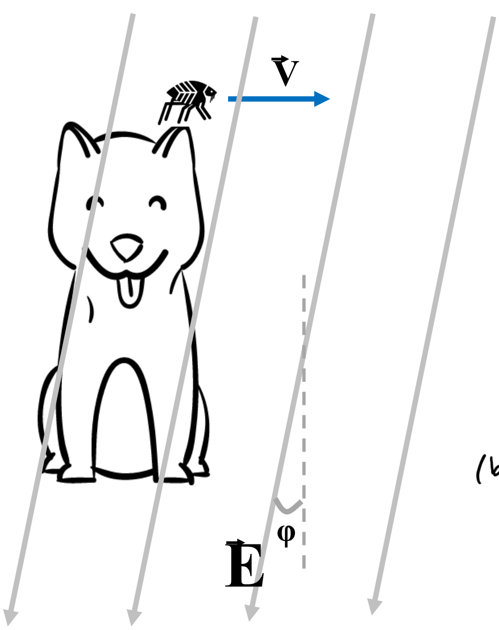
1 pt - mid level explanation - explanation uses relevant physics, but is conceptually incorrect or incomplete

5. (7 points) One way to administer flea medication to an animal is to drop medicine behind their neck. The fumes from the oily fluid kills fleas living on them. Imagine a 2 milligram flea running from these fumes through the fur of a large dog, collecting a net charge through friction equal to -100 nC. The flea then jumps horizontally with speed of 1.9 m/s off the dog into a 200 N/C electric field created by the Earth that points down and towards them at an angle of 20°.

(a) Is the flea in the air (time of flight) longer with the electric field present, not present, or does it not make a difference? Explain using words, figures, math, or other representations. (Ignore air resistance)

(b) What is the acceleration vector of the flea after it jumps off the dog, while it is in the air (ignore air resistance).

(c) *Extra Credit (up to 3 pts)*: How far does the flea fly horizontally when the electric field is present? The flea is initially 1.00 meters above the horizontal ground.



(a) $\vec{F}^E_0 = q_0 \vec{E}$, w/ $q_0(-)$ + $\vec{E}$ ↙, $\vec{F}^E$ ↗

w/ $\vec{F}^g$ ↓, ΣF_y is decreased

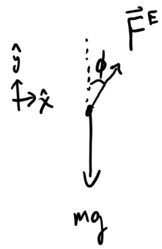
w/ $\Sigma F_y = m a_y$, a_y is decreased

w/ $\Delta y = v_{iy}^{\,0} \Delta t + \frac{1}{2} a_y \Delta t^2$

$\Delta t = \sqrt{\frac{2\Delta y}{a_y}}$, so $a_y \downarrow$, $\Delta t \uparrow$

longer time of flight

(b) FBD (flea)

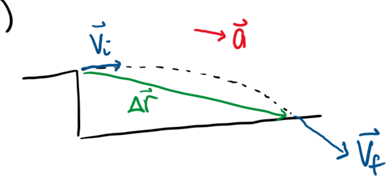


$\Sigma F_y \Rightarrow |\vec{F}^E| \cos\phi - mg = m a_y$

$|q_0||\vec{E}| \cos\phi - mg = m a_y \Rightarrow a_y = \frac{|q_0||\vec{E}|\cos\phi}{m} - g$

$\Sigma F_x \Rightarrow |\vec{F}^E| \sin\phi = m a_x \Rightarrow a_x = \frac{|q_0||\vec{E}|\sin\phi}{m}$

(c)



	K	UK
X	a_x, v_{ix}	$\Delta x, \Delta t, v_{fx}$
Y	$a_y, v_{iy}, \Delta y$	$\Delta t, v_{fy}$

from (a) $\Delta t = \sqrt{\frac{2\Delta y}{a_y}}$, w/ $\Delta x = v_{ix}\Delta t + \frac{1}{2} a_x \Delta t^2$

$$\Delta x = v_{ix}\sqrt{\frac{2\Delta y}{a_y}} + \frac{a_x \Delta y}{a_y}$$

Notice if $a_x = 0$, $\Delta x \downarrow$ .... travels further

free-fall ↗

The world of the small experiences the world differently

Rubric

Part (a) - 3.5 points
- **1 pt - F = qE equation**
- **1 pt - direction of electric force**
- **1 pt - a_y decreased**
- **0.5 pt - correct answer**

Part (b) - 3.5 points
- **0.5 pt - FBD**
- **1 pt - Fnet = m a**
- **1 pt - component analysis**
- **1 pts - algebra**

Part (c) - 3 pts extra credit
- **1 pt - attempted**
- **2 pt - got most of the way through**
- **3 pt - correct work**

6. (9 points) The image below shows a quadrupole arrangement of 4 point charges located at A, B, C, and D, and the electric potential field they create. The value in each square box represents the electric potential (in volts) at the center of the square. Each square is 1.00 meter x 1.00 meter (length x width). The four point charges are located at the center of boxes A, B, C, and D.

(a) What is the sign of each of the 4 point charges, A, B, C, and D? Explain.

(b) If an electron was placed at rest 4 meters directly to the right of charge D at the 0.35 V location, what direction would the electron begin to move? Explain.

(c) A proton is initially 4 meters directly to the right of charge B at the 0.85 V location. The protons has an unknown initial speed at this location. The proton eventually comes to rest momentarily when it is 1 meter to the right of charge B at the 5.16 V location. What was the proton's initial speed at the 0.85 V location? Ignore gravity.

(d) Clearly sketch, and label, the –5 volt equipotential line(s).

0.00	-0.03	-0.07	-0.12	-0.20	-0.29	-0.41	-0.55	-0.69	-0.80	-0.85	-0.80	-0.69	-0.55	-0.41	-0.29	-0.20	-0.12	-0.07	-0.03	0.00
0.03	0.00	-0.04	-0.11	-0.20	-0.32	-0.49	-0.70	-0.95	-1.19	-1.29	-1.19	-0.95	-0.70	-0.49	-0.32	-0.20	-0.11	-0.04	0.00	0.03
0.07	0.04	0.00	-0.07	-0.18	-0.33	-0.56	-0.88	-1.34	-1.91	-2.23	-1.91	-1.34	-0.88	-0.56	-0.33	-0.18	-0.07	0.00	0.04	0.07
0.12	0.11	0.07	0.00	-0.12	-0.30	-0.58	-1.03	-1.83	-3.40	-5.16	-3.40	-1.83	-1.03	-0.58	-0.30	-0.12	0.00	0.07	0.11	0.12
0.20	0.20	0.18	0.12	0.00	-0.20	-0.51	-1.04	-2.06	-5.08	A	-5.08	-2.06	-1.04	-0.51	-0.20	0.00	0.12	0.18	0.20	0.20
0.29	0.32	0.33	0.30	0.20	0.00	-0.32	-0.81	-1.65	-3.24	-5.01	-3.24	-1.65	-0.81	-0.32	0.00	0.20	0.30	0.33	0.32	0.29
0.41	0.49	0.56	0.58	0.51	0.32	0.00	-0.43	-0.98	-1.60	-1.94	-1.60	-0.98	-0.43	0.00	0.32	0.51	0.58	0.56	0.49	0.41
0.55	0.70	0.88	1.03	1.04	0.81	0.43	0.00	-0.41	-0.74	-0.88	-0.74	-0.41	0.00	0.43	0.81	1.04	1.03	0.88	0.70	0.55
0.69	0.95	1.34	1.83	2.06	1.65	0.98	0.41	0.00	-0.26	-0.35	-0.26	0.00	0.41	0.98	1.65	2.06	1.83	1.34	0.95	0.69
0.80	1.19	1.91	3.40	5.08	3.24	1.60	0.74	0.26	0.00	-0.08	0.00	0.26	0.74	1.60	3.24	5.08	3.40	1.91	1.19	0.80
0.85	1.29	2.23	5.16	D	5.01	1.94	0.88	0.35	0.08	0.00	0.08	0.35	0.88	1.94	5.01	B	5.16	2.23	1.29	0.85
0.80	1.19	1.91	3.40	5.08	3.24	1.60	0.74	0.26	0.00	-0.08	0.00	0.26	0.74	1.60	3.24	5.08	3.40	1.91	1.19	0.80
0.69	0.95	1.34	1.83	2.06	1.65	0.98	0.41	0.00	-0.26	-0.35	-0.26	0.00	0.41	0.98	1.65	2.06	1.83	1.34	0.95	0.69
0.55	0.70	0.88	1.03	1.04	0.81	0.43	0.00	-0.41	-0.74	-0.88	-0.74	-0.41	0.00	0.43	0.81	1.04	1.03	0.88	0.70	0.55
0.41	0.49	0.56	0.58	0.51	0.32	0.00	-0.43	-0.98	-1.60	-1.94	-1.60	-0.98	-0.43	0.00	0.32	0.51	0.58	0.56	0.49	0.41
0.29	0.32	0.33	0.30	0.20	0.00	-0.32	-0.81	-1.65	-3.24	-5.01	-3.24	-1.65	-0.81	-0.32	0.00	0.20	0.30	0.33	0.32	0.29
0.20	0.20	0.18	0.12	0.00	-0.20	-0.51	-1.04	-2.06	-5.08	C	-5.08	-2.06	-1.04	-0.51	-0.20	0.00	0.12	0.18	0.20	0.20
0.12	0.11	0.07	0.00	-0.12	-0.30	-0.58	-1.03	-1.83	-3.40	-5.16	-3.40	-1.83	-1.03	-0.58	-0.30	-0.12	0.00	0.07	0.11	0.12
0.07	0.04	0.00	-0.07	-0.18	-0.33	-0.56	-0.88	-1.34	-1.91	-2.23	-1.91	-1.34	-0.88	-0.56	-0.33	-0.18	-0.07	0.00	0.04	0.07
0.03	0.00	-0.04	-0.11	-0.20	-0.32	-0.49	-0.70	-0.95	-1.19	-1.29	-1.19	-0.95	-0.70	-0.49	-0.32	-0.20	-0.11	-0.04	0.00	0.03
0.00	-0.03	-0.07	-0.12	-0.20	-0.29	-0.41	-0.55	-0.69	-0.80	-0.85	-0.80	-0.69	-0.55	-0.41	-0.29	-0.20	-0.12	-0.07	-0.03	0.00

6. (12 points) The image below shows a quadrupole arrangement of 4 point charges, and the electric potential field that this quadrupole arrangement of 4 point charges creates. The value in each square box represents the electric potential (in volts) at the center of the square. Each square is 1.00 meter x 1.00 meter (length x width). Boxes A, B, C, and D are the 4 point charges that made up a quadrupole.

− + − +   V increases closer to +q's

(a) What is the sign of each of the 4 point charges, A, B, C, and D? Explain. decreases closer to −q's

(b) If an electron was placed at rest 4 meters directly to the right of charge D at the 0.35 V location, what direction would the electron begin to move? Explain. Move to left, towards increased V

(c) A proton is initially 4 meters directly to the right of charge B at the 0.85 V location. The protons has an unknown initial speed at this location. The proton eventually comes to rest momentarily when it is 1 meter to the right of charge B at the 5.16 V location. What was the proton's initial speed at the 0.85 V location? Ignore gravity.

(d) Clearly sketch, and label, the –5 volt equipotential line(s).

0.00	-0.03	-0.07	-0.12	-0.20	-0.29	-0.41	-0.55	-0.69	-0.80	-0.85	-0.80	-0.69	-0.55	-0.41	-0.29	-0.20	-0.12	-0.07	-0.03	0.00
0.03	0.00	-0.04	-0.11	-0.20	-0.32	-0.49	-0.70	-0.95	-1.19	-1.29	-1.19	-0.95	-0.70	-0.49	-0.32	-0.20	-0.11	-0.04	0.00	0.03
0.07	0.04	0.00	-0.07	-0.18	-0.33	-0.56	-0.88	-1.34	-1.91	-2.23	-1.91	-1.34	-0.88	-0.56	-0.33	-0.18	-0.07	0.00	0.04	0.07
0.12	0.11	0.07	0.00	-0.12	-0.30	-0.58	-1.03	-1.83	-3.40	-5.16	-3.40	-1.83	-1.03	-0.58	-0.30	-0.12	0.00	0.07	0.11	0.12
0.20	0.20	0.18	0.12	0.00	-0.20	-0.51	-1.04	-2.06	-5.08	A	-5.08	-2.06	-1.04	-0.51	-0.20	0.00	0.12	0.18	0.20	0.20
0.29	0.32	0.33	0.30	0.20	0.00	-0.32	-0.81	-1.65	-3.24	-5.01	-3.24	-1.65	-0.81	-0.32	0.00	0.20	0.30	0.33	0.32	0.29
0.41	0.49	0.56	0.58	0.51	0.32	0.00	-0.43	-0.98	-1.60	-1.94	-1.60	-0.98	-0.43	0.00	0.32	0.51	0.58	0.56	0.49	0.41
0.55	0.70	0.88	1.03	1.04	0.81	0.43	0.00	-0.41	-0.74	-0.88	-0.74	-0.41	0.00	0.43	0.81	1.04	1.03	0.88	0.70	0.55
0.69	0.95	1.34	1.83	2.06	1.65	0.98	0.41	0.00	-0.26	-0.35	-0.26	0.00	0.41	0.98	1.65	2.06	1.83	1.34	0.95	0.69
0.80	1.19	1.91	3.40	5.08	3.24	1.60	0.74	0.26	0.00	-0.08	0.00	0.26	0.74	1.60	3.24	5.08	3.40	1.91	1.19	0.80
0.85	1.29	2.23	5.16	D	5.01	1.94	0.88	0.35	0.08	0.00	0.08	0.35	0.88	1.94	5.01	B	5.16	2.23	1.29	0.85
0.80	1.19	1.91	3.40	5.08	3.24	1.60	0.74	0.26	0.00	-0.08	0.00	0.26	0.74	1.60	3.24	5.08	3.40	1.91	1.19	0.80
0.69	0.95	1.34	1.83	2.06	1.65	0.98	0.41	0.00	-0.26	-0.35	-0.26	0.00	0.41	0.98	1.65	2.06	1.83	1.34	0.95	0.69
0.55	0.70	0.88	1.03	1.04	0.81	0.43	0.00	-0.41	-0.74	-0.88	-0.74	-0.41	0.00	0.43	0.81	1.04	1.03	0.88	0.70	0.55
0.41	0.49	0.56	0.58	0.51	0.32	0.00	-0.43	-0.98	-1.60	-1.94	-1.60	-0.98	-0.43	0.00	0.32	0.51	0.58	0.56	0.49	0.41
0.29	0.32	0.33	0.30	0.20	0.00	-0.32	-0.81	-1.65	-3.24	-5.01	-3.24	-1.65	-0.81	-0.32	0.00	0.20	0.30	0.33	0.32	0.29
0.20	0.20	0.18	0.12	0.00	-0.20	-0.51	-1.04	-2.06	-5.08	C	-5.08	-2.06	-1.04	-0.51	-0.20	0.00	0.12	0.18	0.20	0.20
0.12	0.11	0.07	0.00	-0.12	-0.30	-0.58	-1.03	-1.83	-3.40	-5.16	-3.40	-1.83	-1.03	-0.58	-0.30	-0.12	0.00	0.07	0.11	0.12
0.07	0.04	0.00	-0.07	-0.18	-0.33	-0.56	-0.88	-1.34	-1.91	-2.23	-1.91	-1.34	-0.88	-0.56	-0.33	-0.18	-0.07	0.00	0.04	0.07
0.03	0.00	-0.04	-0.11	-0.20	-0.32	-0.49	-0.70	-0.95	-1.19	-1.29	-1.19	-0.95	-0.70	-0.49	-0.32	-0.20	-0.11	-0.04	0.00	0.03
0.00	-0.03	-0.07	-0.12	-0.20	-0.29	-0.41	-0.55	-0.69	-0.80	-0.85	-0.80	-0.69	-0.55	-0.41	-0.29	-0.20	-0.12	-0.07	-0.03	0.00

−5V   −5V

(c) $KE_{Ti} + U^E_i + W_{ext} + Q = KE_{Tf} + U^E_f$

$KE_{Ti} + U^E_i = U^E_f$

$\frac{1}{2}mv_i^2 + qV_i = qV_f$

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

$\frac{1}{2}(1.67\times10^{-27}\text{ kg})v_i^2 = (1.6\times10^{-19}\text{ C})(5.16 - 0.85)$

$v_i = 28738$ m/s