

Solution

$$\begin{aligned} & 120 \text{ max} \\ & \underline{\underline{19 = 100\%}} \\ & \Rightarrow 60\% = 11.4 \end{aligned}$$

NYB Test 1 (Day sections)

Student ID number: _____

Student Name : _____

Initials: _____

Instructions (Please read carefully)

General Instructions

- **Time :** 120 minutes
- **Permitted materials:**
 - 3" x 5" formula sheet, handwritten, one side only
 - Pens, Pencils, Rulers, Protractors, Erasers
 - A simple calculator

Before the exam

- Switch off your phones and put them with your bags at the whiteboard.
- Put your ID card on the table.

During the exam

- Please answer all questions on the question sheet. Use the back of the sheets if you run out of space.
- You may do the questions in any order you choose. Watch your time carefully. I suggest you start with the ones you feel you can do correctly and quickly.
- Before you leave, please:
 - Be sure you've written your name on the first, and your initials on all following pages.
 - To hand in all papers
 - Initial the sign-up list, confirming hand in.

Cheating

Any attempt in cheating (using of non permitted documentation, collaboration and copying, as well as having a cell phone in reach) will result in a test mark of zero and is reported to the administration.

GOOD LUCK!

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Some constants:

Charge of an electron:	$-1.6 \times 10^{-19} \text{ C}$	Mass of an electron:	$9.109 \times 10^{-31} \text{ kg}$
Charge of a proton:	$+1.6 \times 10^{-19} \text{ C}$	Mass of a proton:	$1.6726 \times 10^{-27} \text{ kg}$
Charge of an alpha particle:	$+3.2 \times 10^{-19} \text{ C}$	Mass of an alpha particle:	$6.6442 \times 10^{-27} \text{ kg}$
g :	10 m/s^2	k :	$9.00 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$
ϵ_0 :	$8.85 \times 10^{-12} \text{ F/m}$	μ_0 :	$4\pi \times 10^{-7} \text{ H/m}$
c :	$3 \times 10^8 \text{ m/s}$		

Question 1 : 1 point

Select for each of the following, if the statement is true or false. Mark an "x" in the appropriate column. No justification needed.

	True	False
All conductors are metals		X
An object can only be charged by transfer of electrons		X
A positive charge moves <u>always</u> in the direction of the electric field lines		X
The electric field is a scalar field		X

Question 2 : 1 point

Based on the triboelectric series on the right, determine the charge (+ or -) of human hair:

- a) when rubbed against wood
b) when rubbed against rabbit fur

No justification needed

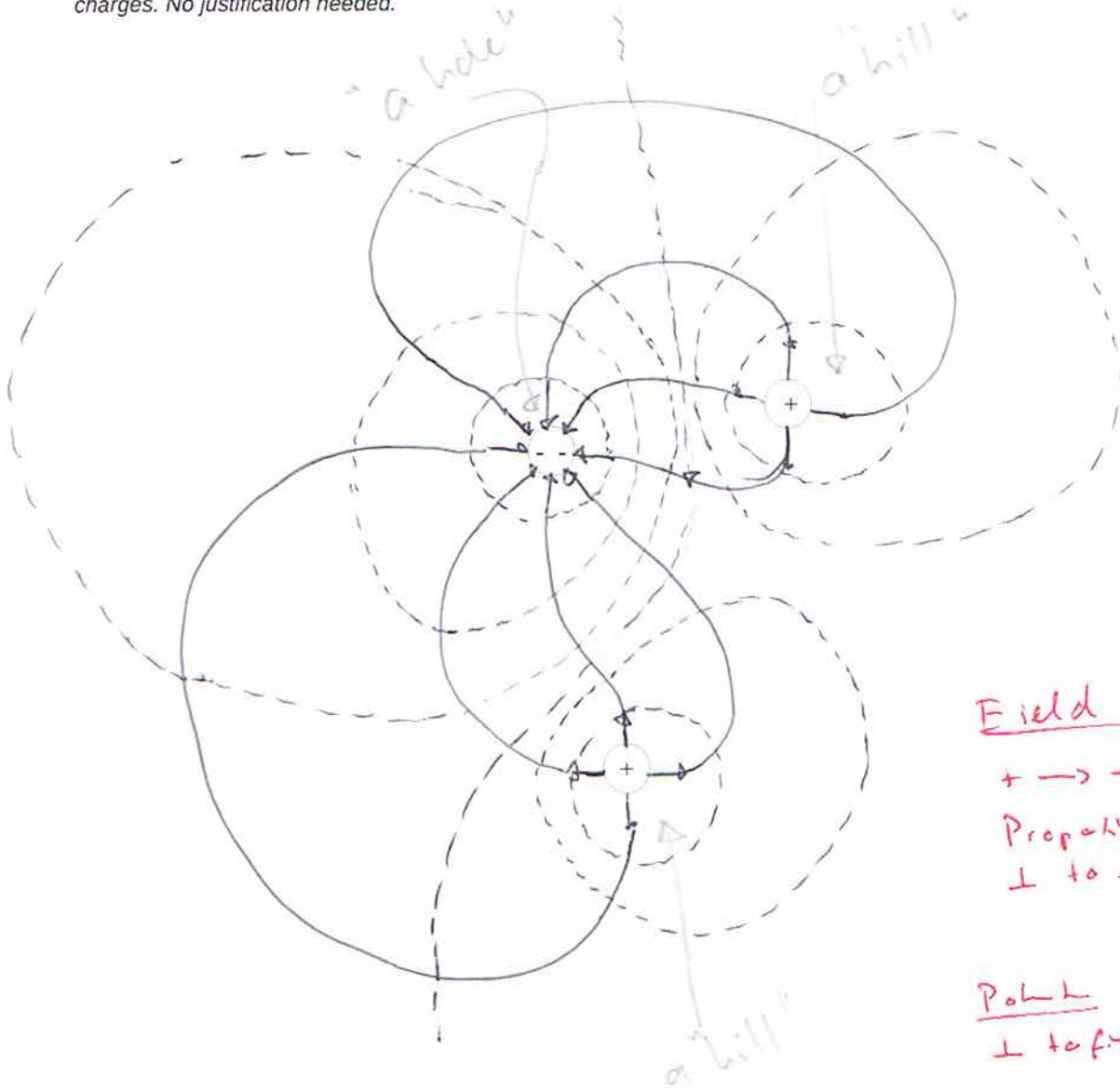
- Human hands *Very positive*
- Rabbit Fur
- Glass
- Human hair
- Paper
- Cotton
- Wood
- Silicon
- Teflon *Very negative*

a) + ✓
b) - ✓

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Question 3 : 2 points

Draw the electric field lines (solid) and the equipotential lines (dashed) for the following distribution of charges. No justification needed.



$V = 0.5$

Field Lines

- + → - ✓
- Proportional ✓
- ⊥ to surface -

Potential

- ⊥ to field ✓

field lines crowded -1/4
not prop'n -1/2

potential "hole"
@ ⊖ missing

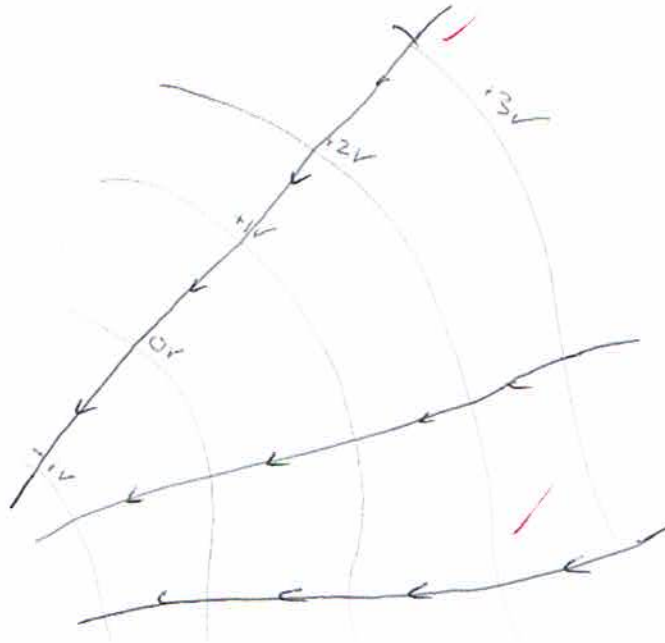
Straight field lines -1/2
p = 1/r -1/4

Field lines "trapped"

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Question 4 : 1 point

For the following pattern of equipotential lines, draw the electric field lines (mark the direction of the field lines). *No justification needed.*



\perp ✓
+ → - ✓

uniform field - 1/4

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For all the following questions, answers without justification (or step by step solutions) will get zero points

Question 4 : 1 point

What is the charge in coulombs of an object that has a deficiency (less electrons than protons) of 1.0×10^4 electrons?

$$\underline{Q} = N \cdot e = \underline{+1.6 \times 10^{-15} \text{ C}}$$

↓
positive charge

Question 5: 1 point

A potential difference of 25'000 V is used to accelerate an electron from rest. What is the final speed of the electron? (calculate without relativistic effects)

$$\Delta PE = \Delta KE$$

$$e \cdot \Delta V = \frac{1}{2} m_e v^2$$

$$\underline{v} = \sqrt{\frac{2e \cdot \Delta V}{m_e}} = \underline{0.93 \times 10^8 \text{ m/s}}$$

(= 0.31c!)

9.3 × 10⁷ m/s
"

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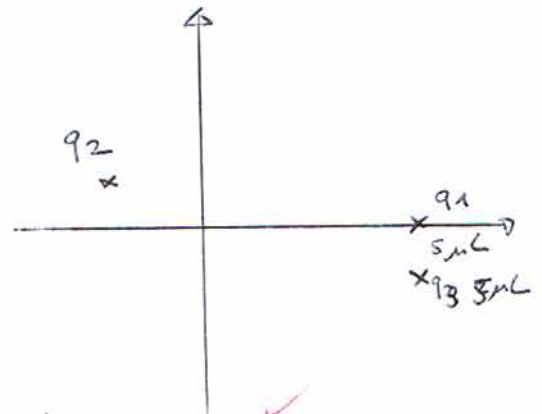
Question 6 : 4 points

Three charged particles are placed at the following positions:

$$q_1 = +5 \mu\text{C}, \vec{r}_1 = [10\hat{i}, 0\hat{j}] \text{m}$$

$$q_2 = +2 \mu\text{C}, \vec{r}_2 = [-4\hat{i}, 2\hat{j}] \text{m}$$

$$q_3 = +5 \mu\text{C}, \vec{r}_3 = [10\hat{i}, -2\hat{j}] \text{m}$$



a) What is the force (vector !) of charge 1 on charge 3 ? [1 point]

b) What is the net force (vector !) on charge 1 ? [2 points]

c) What is the electric field at the location of charge 1 [1 point]

$$a) \vec{F}_{31} = k \cdot \frac{q_1 q_3}{r_{13}^2} \cdot \hat{r}_{13} = k \cdot \frac{5 \mu\text{C} \times 5 \mu\text{C}}{4 \text{m}^2} \times (-\hat{j}) = \underline{\underline{-56.25 \text{ mN } \hat{j}}}$$

$$(-5.6 \times 10^{-2} \text{ N } \hat{j})$$

$$b) \vec{F}_{\text{net}} = \vec{F}_{13} + \vec{F}_{12}$$

$$\vec{F}_{12} = k \cdot \frac{q_1 q_2}{r_{12}^2} \cdot \frac{(+14\hat{i} - 2\hat{j})}{\sqrt{14^2 + 2^2}} = (4.45 \times 10^{-4} \hat{i} - 6.36 \times 10^{-5} \hat{j}) \text{N}$$

$$\vec{F}_{13} = -\vec{F}_{31} = +5.6 \times 10^{-2} \text{ N } \hat{j}$$

$$\Rightarrow \underline{\underline{\vec{F}_{\text{net}} = \vec{F}_{13} + \vec{F}_{12} = (+4.45 \times 10^{-4} \hat{i} + 5.6 \times 10^{-2} \hat{j}) \text{N}}}$$

$$c) \underline{\underline{\vec{E}_{\text{net}} = \frac{\vec{F}_{\text{net}}}{q_1} = (0.9 \hat{i} + 11.237 \hat{j}) \text{ N/C}}}$$

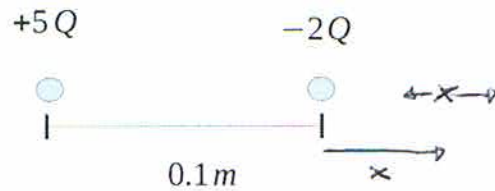
(Field strength: 11.237 N/C)
Partial Points
 $v = 0.5$
 $(v) = 0.25$

~~1/4 for missing vector signs~~

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Question 7 : 2 points

Two point charges of $+5Q$ and $-2Q$ are placed 1m apart. Where (give the distance and direction from one of the charges), except at infinity, is the electric field zero?



$$E_1 = E_2$$

$$k \cdot \frac{15Q}{(0.1+x)^2} = k \cdot \frac{2Q}{x^2}$$

$$5x^2 = 2(0.1+x)^2$$

$$5x^2 = 2(0.1^2 + 0.2x + x^2)$$

$$0 = -3x^2 + 0.4x + 2 \times 0.1^2$$

$$\rightarrow x_1 = -3.8 \times 10^{-2}$$

$$x_2 = \underline{0.172}$$

\Rightarrow 0.172m right of -2Q

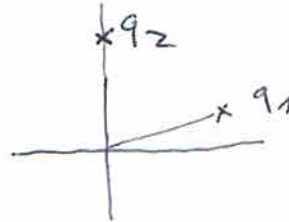
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Question 8: 3 points

Two charges are placed as follows :

$$q_1 = +10 \mu\text{C}, \vec{r}_1 = [4\hat{i}, 1\hat{j}] \text{m}$$

$$q_2 = -2 \mu\text{C}, \vec{r}_2 = [0\hat{i}, 5\hat{j}] \text{m}$$



How much energy would it take to bring a third charge, $q_3 = +10 \mu\text{C}$, to the origin of the coordinate system (From infinity).

$$V_0(0,0) = k \cdot \frac{q_1}{r_1} + k \cdot \frac{q_2}{r_2} \checkmark$$

$$= k \cdot \left(\frac{+10 \mu\text{C}}{\sqrt{4^2 + 1^2}} + \frac{-2 \mu\text{C}}{5} \right)$$

$$= \cancel{18228 \text{ V}} - \cancel{294 \text{ V}} - 3600 \text{ V} = \underline{1699 \text{ V}}$$

$$= 21828 \text{ V} - 3600 \text{ V} = \underline{18228 \text{ V}} \checkmark$$

$$\underline{\Delta U} = q_3 \cdot \Delta V = 10 \mu\text{C} \times 18228 \text{ V} = \underline{0.182 \text{ J}} \checkmark$$

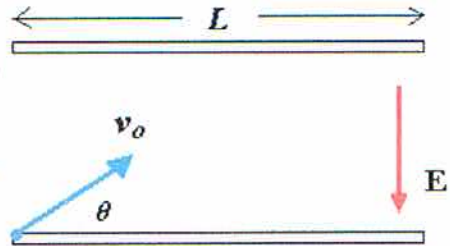
-0.25 if the sig figs were wrong

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Question 9: 4 points

A uniform electric field $\vec{E} = -1000 \hat{j} \text{ N/C}$ exists between two plates of length $L = 10 \text{ cm}$.

An alpha particle is fired at $t = 0 \text{ s}$ with 100 m/s at an angle of $\theta = 30^\circ$ as shown.



- What is the electrostatic force (vector) on the particle [0.5 points]
- What is the acceleration (vector) of the particle [0.5 points]
- Where is the particle (x- and y- coordinates) after 1.00 ms ? [2 points]
- What is the work done by the electric field on the particle between 0 and 1.00 ms ? [1 point]

Ignore gravity

*Partial Points:
v = 0.1
(v) = 0.21
~~Work done by electric field~~*

a) $\vec{F} = q\vec{E} = +3.2 \times 10^{-19} \text{ C} \cdot (-1000 \hat{j}) \text{ N/C} = \underline{-3.2 \times 10^{-16} \hat{j} \text{ N}}$

b) $\vec{a} = \frac{\vec{F}}{m} = \underline{-4.8 \times 10^{10} \hat{j} \text{ m/s}^2}$

c) $x = v_x t = 100 \text{ m/s} \cdot \cos(30) \cdot 0.001 \text{ s} = \underline{0.0866 \text{ m}} \quad (8.66 \text{ cm})$

$y = v_y t + \frac{1}{2} a t^2 = 50 \text{ m/s} \cdot 0.001 \text{ s} - 0.5 \cdot 4.8 \times 10^{10} (0.001)^2$
 $= \underline{-2.4081 \text{ m}} \quad = -2.4 \times 10^4 \text{ m}$

d) ~~Work done by electric field = qE \cdot s~~
 $\underline{W_{el}} = \vec{F}_e \cdot \vec{s} = q \cdot \vec{E} \cdot \vec{s} = q \cdot (0, -1000 \text{ N/C}) \cdot (0.0866 \text{ m}, -2.4081 \text{ m})$
 $= \underline{7.7 \times 10^{-12} \text{ J}}$