Physics 122A
Spring 2019

122A-TOLICH

Exam 1
April 25, 2019

Printed Name SMITH JOHN **Seat Number** F11
last *first*

I certify that the work I shall submit is my own creation, not copied from any source, and that I shall abide by the examination procedures outlined below.

Signature _____ **Student ID Number** 1282372

READ THIS ENTIRE PAGE NOW, BEFORE THE HALF-HOUR BELL.
Do not open the exam before the half-hour bell.
You will have 60 minutes after the bell to complete the examination.
Exam papers will no longer be accepted after 61 minutes have elapsed.
NO CELL PHONES, TEXT MSG, etc. ALLOWED AT ANY TIME

Before the exam begins:

- Print and sign your name, and write your student ID number and the number of your seat in the spaces on this page (above).
- Write your name and student ID number on your bubble sheet, and fill in the corresponding "bubbles" using **dark** pencil marks.

During the exam:

- **Important first step:** Print your name and student ID at the top of **each** page.
- If you are confused about a question, raise your hand and ask for an explanation.
- If you cannot do one part of a problem, move on to the next part.
- This is a closed book examination. You have access to the equation sheet included with this exam and to things written on the classroom board by the instructor.
- You may use a calculator, but you **may not use** text storage capabilities, graphics capabilities, internet connections, phones, nor any programmable device.
- You may not use scratch paper, you may not communicate with any person.

For multiple-choice problems (those on white paper):

- Fill in bubble sheets carefully and **darkly**. Make no stray marks. Erase carefully.
- Also circle your choices directly on the exam paper for later reference.

For hand graded problems (those on colored paper):

- If you need more space than is available to answer any part of a problem, use the **back side of the same page** to complete your answer. Clearly indicate to the grader that you used the back side. Do not use scratch paper.
- Show your work in enough detail so that the grader can follow your reasoning and your method of solution. Circle your answers, and state units if appropriate. For numerical answers significant figures should match the number of significant figures in the numerical values given in the problem (usually 2 or 3).

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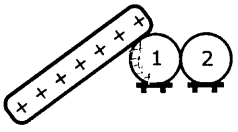
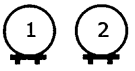
I. Lecture multiple choice (40 points – 8 questions)

1) (5 pts.) Two initially uncharged metallic spheres are in contact and are resting on insulating stands. As shown in figure a), you touch sphere 1 with a positively charged rod. Then the charged rod is removed. Finally, sphere 2 is moved slightly so that it is not in contact with sphere 1, as shown in figure b). What is the sign of the charge on each sphere in this final state?

a)



b)



A. Sphere 1 is negatively charged and sphere 2 is uncharged.
B. Sphere 1 is negatively charged and sphere 2 is positively charged.
C. Sphere 1 is positively charged and sphere 2 is negatively charged.
(D.) Spheres 1 and 2 are both positively charged.
E. Spheres 1 and 2 are both negatively charged.

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2) (5 pts.) Two charged particles labeled A and B are separated by a distance. If the charge of particle B is doubled, which of the following statements most correctly describes the change?

(A.) The magnitude of the electric force exerted on A is doubled because the electric field at the position of A is doubled.
B. The magnitude of the electric force exerted on B is doubled because the electric field at the position of B is doubled.
C. The magnitude of the electric force exerted on A is doubled because the electric field at the position of B is doubled.
D. The magnitude of the electric force exerted on B is doubled because the electric field at the position of A is doubled.

A ——d——> B, x2

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3) (5 pts.) A uniformly charged thin rod lies along the x axis from $x = 0$ to $x = \infty$. The rod has linear charge density λ. You wish to derive an expression for the electric field in the y direction at any point along the y axis using Coulomb's law. Which of the following expressions represent the integral you should solve?

A. $E_y(y) = \int_0^\infty \frac{k\lambda}{(x^2+y^2)}dx$
B. $E_y(y) = \int_0^\infty \frac{k\lambda y}{x^3}dx$
C. $E_y(y) = \int_0^\infty \frac{k\lambda}{x^2}dx$
D. $E_y(y) = \int_0^\infty \frac{k\lambda x}{(x^2+y^2)^{3/2}}dx$
(E.) $E_y(y) = \int_0^\infty \frac{k\lambda y}{(x^2+y^2)^{3/2}}dx$

$E_y = \frac{2k\lambda}{y}$

$\frac{2k\lambda}{x} = \frac{2k\lambda}{r}$

$2k\lambda$

$E =$

$\frac{2k\lambda}{\sqrt{x^2+y^2}} \times \frac{\sin\theta}{1} = \frac{y}{\sqrt{x^2+y^2}}$

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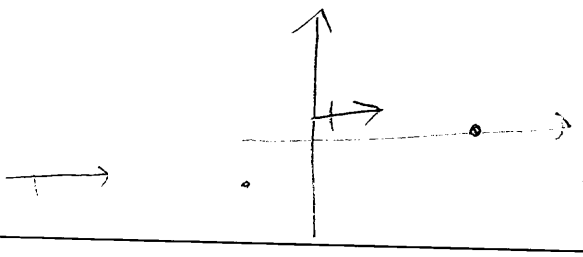
4) (5 pts.) A water molecule is centered at the origin of a coordinate system with its dipole moment vector aligned with the x axis. The magnitude of a water molecule dipole is 6.16×10^{-30} C·m. What is the magnitude of the electric field at $x = 3.00 \times 10^{-9}$ m?

A. 1.8×10^{-11} N/C
B. 6.2×10^{-3} N/C
C. 1.2×10^{-2} N/C
D. 2.1×10^{6} N/C
(E.) 4.1×10^{6} N/C

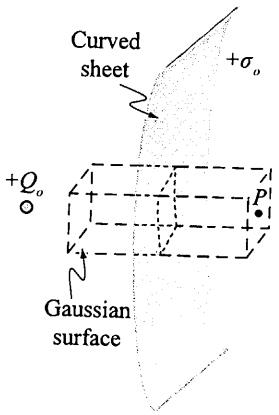


$\frac{2kp}{y^3}$

$\frac{2(10e9 \times 9)(6.16e-30)}{(3e-9)^3}$

Use the following situation for the next two problems.

A Gaussian surface in the shape of a rectangular prism is centered in the middle of a very large curved sheet as shown at right. The curved sheet has a uniform charge density $+\sigma_o$. Only a portion of the sheet is shown. Point *P* is at the center of the right end-cap of the Gaussian surface.



A positive point charge $+Q_o$ is placed on the left side of the sheet as shown.

5) (5 pts.) Select the statement that best describes how the magnitude of the net electric field at point *P* changes when $+Q_o$ is added.

(A.) The magnitude of the net electric field at point *P increases*.
B. The magnitude of the net electric field at point *P decreases*.
C. The magnitude of the net electric field at point *P stays the same*.
D. There is not enough information to answer.

6) (5 pts.) Select the statement that best describes how the net electric flux through the Gaussian surface changes when $+Q_o$ is added.

A. The electric flux through the surface *increases*.
B. The electric flux through the surface *decreases*.
(C.) The electric flux through the surface *stays the same*.
D. There is not enough information to answer.

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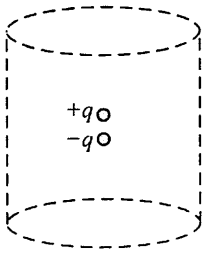
7) (5 pts.) Consider the following charge distribution and Gaussian surface, as shown. The charges lie on the central axis of the cylinder and the midpoint between the charges is at the center of the cylinder. Which of the following statements about the electric flux on the Gaussian surface is true?



(A) The electric flux is ***zero*** on every part of the surface.
B. The electric flux is ***negative*** on most of the surface.
C. The electric flux is ***positive*** on most of the surface.
D. The electric flux is ***negative*** on half of the surface and ***positive*** on the other half.
E. There is not enough information to answer.

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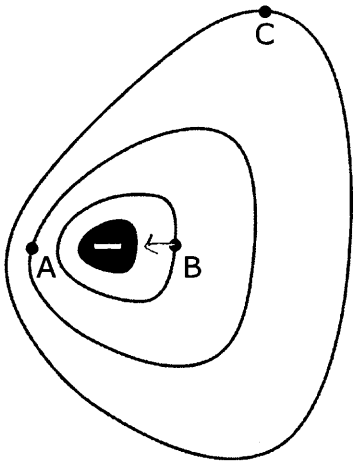
8) (5 pts.) The figure to the right shows a charge distribution and three corresponding equipotential lines. Which of the following statements are correct comparing the three labelled points?



A. The magnitude of the electric field is greatest at point A. ✓
B. The potential is greatest point C. ✓
C. The electric field points approximately to the left at point B.
D. A and C.
(E.) All of the above.

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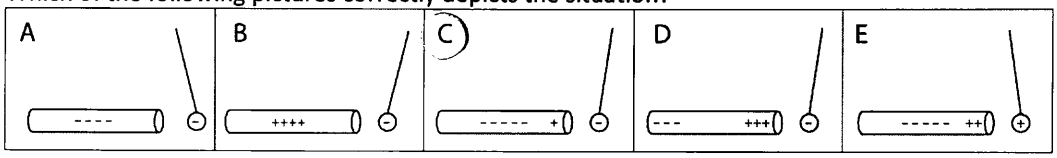
II. Lab multiple choice (16 points – 4 questions)

9) (4 pts.) In Lab 1, assume you did the following operation: First touch the small acrylic rod with your hand thoroughly so it is uncharged and clean it with the alcohol and paper towel; Scrape a charged Teflon rod along the center of the small acrylic rod, then charge the pith ball by touching it to the charged Teflon rod. Dangle the charged pith ball by its string near the right end of the acrylic rod. Which of the following pictures correctly depicts the situation?



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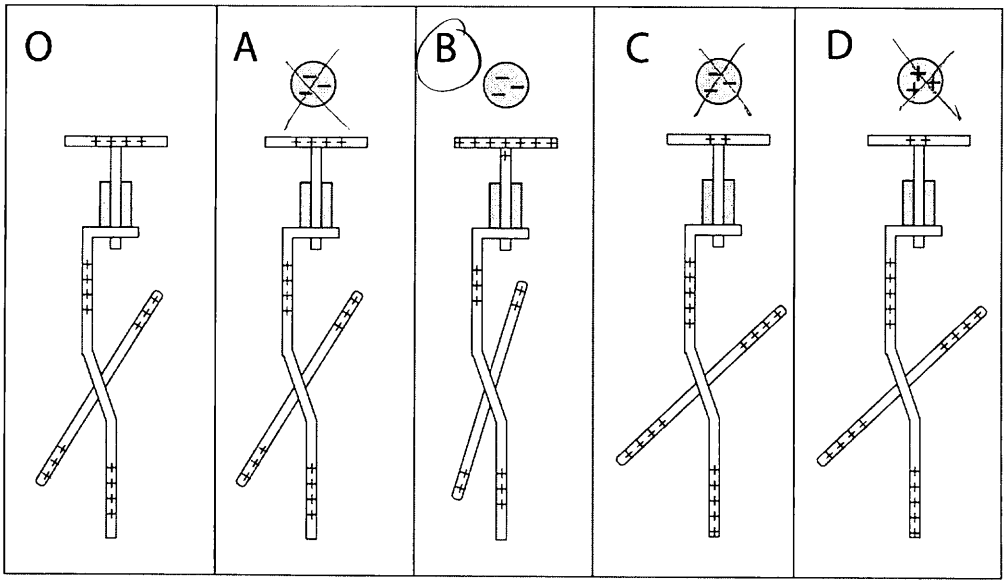
10) (4 pts.) An electroscope is initially neutral. You first scrape the disk of the electroscope with an acrylic rod that has been rubbed with a wool cloth. Picture O below shows the situation after this step. Then a Teflon rod that has been rubbed with a wool cloth is held near the disk without touching the disk, nor generating any sparks. Which of the following pictures correctly depicts the situation? Note both the charge distribution and the vane position.



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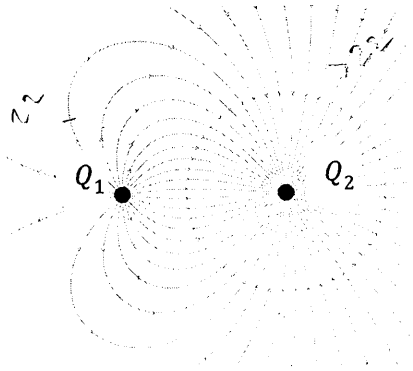
11) (4 pts.) The electric field lines between two charges Q_1 and Q_2 are depicted in the image to the right. Which of the following can be the possible values of Q_1 and Q_2?

A. $Q_1 = 1$ nC and $Q_2 = 1$ nC
~~B. $Q_1 = -1$ nC and $Q_2 = 2$ nC~~
C. $Q_1 = 1$ nC and $Q_2 = -2.5$ nC
~~D. $Q_1 = -2.5$ nC and $Q_2 = 1.5$ nC~~
~~E. $Q_1 = -2$ nC and $Q_2 = -3.5$ nC~~

$Q_1 > 0$
$Q_2 < 0$



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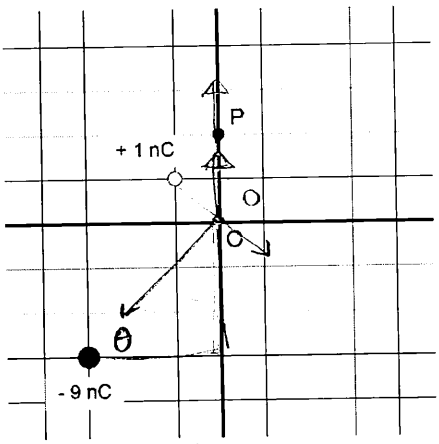
12) (4 pts.) Two charges, +1 nC and –9 nC are placed on a planar grid as shown on the right. What value of charge should be placed at point P so that the electric field at the origin is zero?

A. 2 nC
B. -2 nC
C. $2\sqrt{2}$ nC
D. $-2\sqrt{2}$ nC
E. $\sqrt{3}$ nC



$E = \frac{KQ}{r^2} = 6.36$

$\frac{6.36 \times 2^2}{9e9} = Q =$

-2.8

$E_{Px} = \frac{K(-9e-9)}{18}\cos 45° = -3.18$

$E_{Py} = -13.5$

$E_x = \frac{K(1e-9)}{2} \times \frac{1}{\sqrt{2}} = -3.18$

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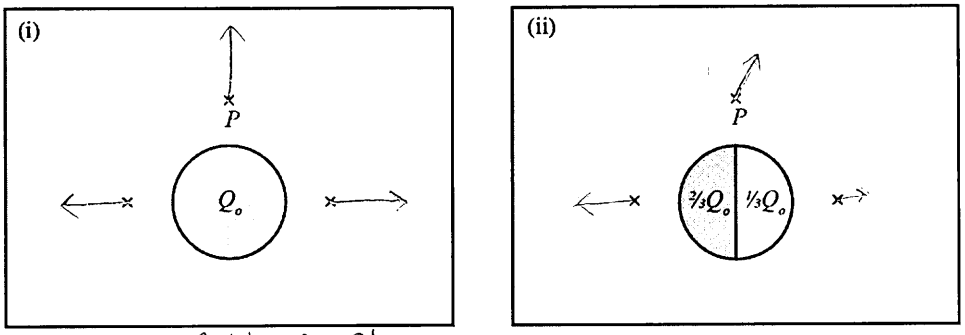
IV. [18 points total] Tutorial questions.

The figure below shows cross-sectional views through the centers of two charged spheres. Both spheres have total positive charge Q_o. Sphere (i) has charge evenly distributed throughout its volume; sphere (ii) has more charge concentrated on the left side of the sphere than on the right. ② P



all fields equal

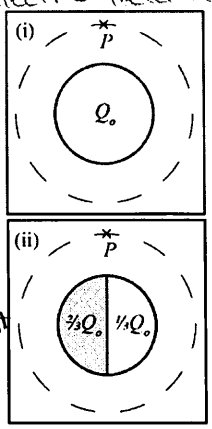
A. [6 pts] Draw a vector indicating the direction and relative magnitude of the electric field at each of the three marked points on each diagram. All marked points are the same distance from the center of their respective sphere. No explanation required.

6 $E \propto \frac{Q}{r^2}$ if r is equal $E \propto Q$

B. [4 pts] Is the direction of the electric field at point P for sphere (i) the same as for sphere (ii)? Explain why or why not.

4 No. In sphere 1 the charge is evenly distributed so the horizontal components of the electrical field vectors at point P cancel out and there is only a net y-component for the electric field. In sphere 2 the charge is unevenly distributed and the x-components of the electric field vectors due to the left side are larger than the x-components of the electric field vectors due to the right. The x-components do not cancel and there is a net positive x-component AND a net positive y-component to the electric field at P.

The same two charge distributions are reproduced at right. Each is enclosed by a concentric spherical Gaussian surface. Both surfaces have the same radius.



C. Let E_P be the magnitude of the electric field at point P in each case and let A be the surface area of the Gaussian surface. In each case, state whether the integral of the electric flux through the Gaussian surface $\Phi_E = \int \vec{E} \cdot d\vec{A}$ can be written as $\Phi_E = E_P A$. Explain why or why not.

(i) [4 pts]

4 Yes. $\Phi_E = E_P A$ is valid when the angle between $\vec{dA}$ and $\vec{E}$ is 90° at every point on the surface. Since the charge is equally distributed and the component of the electric field perpendicular to $\vec{dA}$ is the same at every point, $\Phi_E = \int \vec{E} \cdot \vec{dA}$ can be simplified to $\Phi_E = E_P A$.

(ii) [4 pts]

3 No. The electric field is not perpendicular to $\vec{dA}$ at every point due to the uneven distribution of charge. As a result $\cos\theta$ will not always equal 1 and $\Phi_E = \int \vec{E} \cdot \vec{dA}$ cannot be simplified to $\Phi_E = E_P A$

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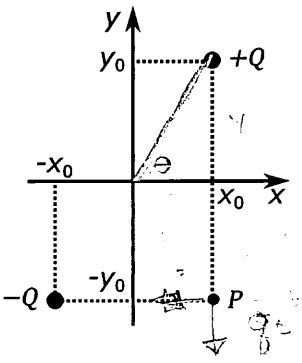
III. Lecture free response (26 points total)

Show enough work to get partial credit.

A positive charge $+Q$ is located at (x_0, y_0) and a negative charge $-Q$ is located at $(-x_0, -y_0)$, as shown.



A. (6 pts) What is the electric field **vector** at position P in terms of variables given and fundamental constants?

$\vec{E} = k\frac{q}{r^2}\hat{r} \rightarrow \vec{E}_{+Q} = \frac{-KQ}{(2y_0)^2}\hat{j}$ & $\vec{E}_{-Q} = \frac{K(-Q)}{(2x_0)^2}\hat{i}$

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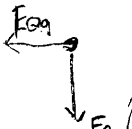
$$\vec{E} = \frac{-KQ}{(2y_0)^2}\hat{i} + \frac{-KQ}{(2x_0)^2}\hat{j}$$

B. (6 pts) A positive charge $+q_t$ is now added at position P, what is the magnitude of the force on $+q_t$ in terms of variables given and fundamental constants?



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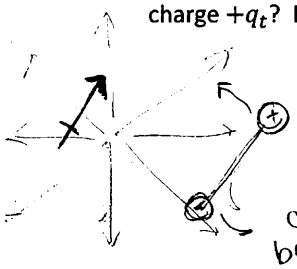
$|F_{-Qq}| = \left|\frac{K(-Q)(q)}{(2x_0)^2}\right| = |F_x|$ $\quad |F_{Qq}| = |F_y| = \left|\frac{(-Q)(q)K}{(2y_0)^2}\right|$ & $F = \sqrt{F_x^2 + F_y^2}$

$$F = \sqrt{\left(\frac{KQq}{4x_0^2}\right)^2 + \frac{(KQq)^2}{(4y_0^2)^2}} = \frac{KQq}{4}\left(\frac{1}{x_0^2} + \frac{1}{y_0^2}\right) = F$$

C. (7 pts) You then connect charges $+Q$ and $-Q$ by a uniform thin insulating rod, so that the distance between them is fixed. The charge $+q_t$ is fixed in position, but the other charges are free to move. If $x_0 < y_0$, does the center of the rod move *toward*, *away from*, or *remain stationary* relative to charge $+q_t$? Explain.



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Towards the charge $+q_t$. The electric field is not uniform so the center of the rod moves due to the electric field's effect on the charges. If $x_0 < y_0$ then negative charge is closer to the $+q_t$ charge than the $+Q$ charge is and the $-Q$ charge feels a stronger field. It will be attracted to the $+q_t$ charge and move the rod towards the charge.

D. (7 pts) As shown below, q_t and the rod are removed and a very large horizontal conducting slab with zero initial charge is placed between the charges $+Q$ and $-Q$. Draw the approximate electric field lines on the diagram below.

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