Physics 122 A
Winter 2025

122A - N.TOLICH

Midterm 1
January 30th, 2025

Please use the boxes below to <u>clearly print</u> your name and UW NetID.
<u>Please write within the boxes</u>.

Printed Name	

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I certify that the work I shall submit is my own creation, not copied from any source.

Signature __________________________________ Seat Number __________________

Clearly fill out this cover page and the top portion of the provided bubble sheet with the necessary information.

Do <u>not</u> open the exam until told to do so.
When prompted, clearly print the information required at the top of <u>each page</u> of this exam booklet.
You can remove the equation sheet(s). Otherwise, keep the exam booklet intact.
You will have <u>60 minutes</u> to complete the examination.

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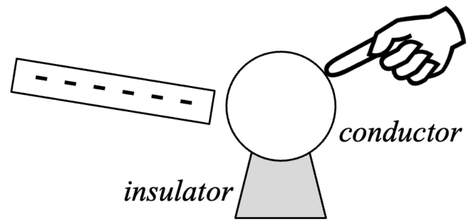
I. Lecture multiple choice (45 points – 9 questions)

1) (5 pts) A conducting sphere on an insulating stand initially has no net charge. A student touches the sphere while they bring a negatively charged rod near to the sphere. In which of the following cases will the sphere end up with a net positive charge?
   I. The student first removes their hand from the sphere, then removes the charged rod.
   II. The student first removes the charged rod, then removes their hand from the sphere.



   A. I. only
   B. II. only
   C. Both cases.
   D. Neither case.
   E. There is not enough information to tell.

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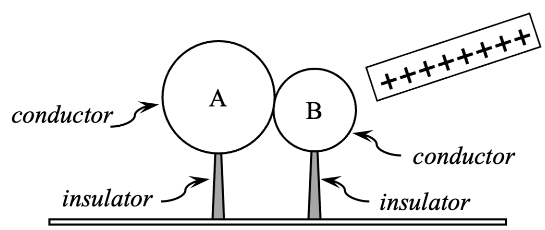
2) (5 pts) Two initially neutral, conducting spheres are on insulating stands. The spheres are placed in contact with each other. A positively charged rod is brought near to, but not touching, sphere B, as shown. While the rod is held in place, the conducting spheres are separated using the insulating stands. After they are separated, how does the absolute value of the charge on sphere A compare to the absolute value of the charge on sphere B?



   A. $|q_A| > |q_B|$
   B. $|q_A| < |q_B|$
   C. $|q_A| = |q_B|$
   D. There is not enough information to tell.

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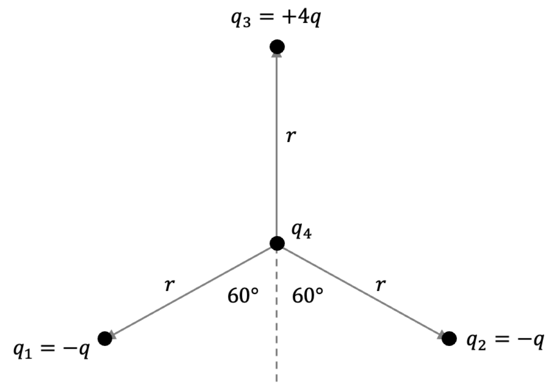
3) (5 pts) Particle A experiences a force $\vec{F} = +9.0 \times 10^{-9}\ \mathrm{N}\ \hat{\imath}$ in a uniform electric field. Particle A is replaced by particle B, which experiences a force $\vec{F} = -12.0 \times 10^{-9}\ \mathrm{N}\ \hat{\imath}$. What is the charge of particle B in terms of the charge of particle A?

   A. $q_B = 0.75\, q_A$
   B. $q_B = -0.75\, q_A$
   C. $q_B = 1.33\, q_A$
   D. $q_B = -1.33\, q_A$
   E. None of the above.

4) (5 pts) Four charged particles are arranged as shown. The charges of the particles are $q_1 = q_2 = -q$ and $q_3 = 4q$. What is the magnitude of the force exerted on charge q_4 by the other three charges?

A. $3.0\frac{Kqq_4}{r^2}$
B. $5.0\frac{Kqq_4}{r^2}$
C. $5.7\frac{Kqq_4}{r^2}$
D. $4.5\frac{Kqq_4}{r^2}$
E. None of the above



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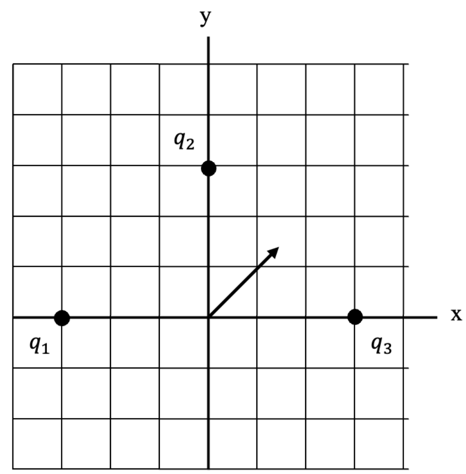
5) (5 pts) Three charged point particles are arranged as shown. Particle 2 has a charge $q_2 = -q$. The net electric field at the origin makes a $45°$ angle with the positive x-axis. Which of the following is possible for the charges on particles 1 and 3?

A. $q_1 = +q$ and $q_3 = +2q$
B. $q_1 = +2q$ and $q_3 = -q$
C. $q_1 = -q$ and $q_3 = -2q$
D. $q_1 = -q$ and $q_3 = +2q$
E. None of the above.



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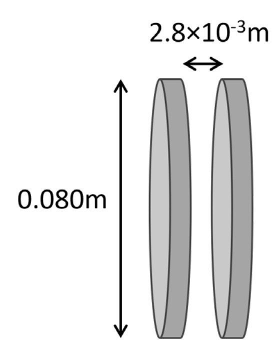
6) (5 pts) A parallel-plate capacitor is formed from two 0.080-m-diameter plates (electrodes) spaced 2.8×10^{-3} m apart. The electric field strength inside the capacitor is 1.0×10^{6} N/C. What is the magnitude of the charge on each plate (electrode)?

A. 2.0×10^{-9} C
B. 2.2×10^{-8} C
C. 4.4×10^{-8} C
D. 8.9×10^{-8} C
E. 1.8×10^{-7} C



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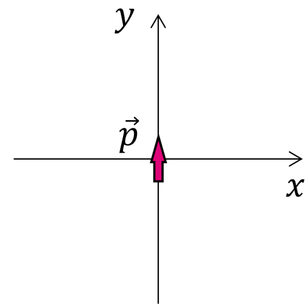
Use the following setup for the next two questions.



An electric dipole is formed from two charges, $+q$ and $-q$, spaced 1.2×10^{-3} m apart. The dipole is at the origin, oriented along the y-axis, as shown.

7) (5 pts) The electric field strength on the y-axis at $y = 0.10$ m is 380 N/C. What is the charge q?

A. 2.1×10^{-11} C
B. 4.2×10^{-11} C
C. 4.2×10^{-10} C
D. 1.8×10^{-8} C
E. 3.5×10^{-8} C

8) (5 pts) Now a positively charged particle is placed on the y-axis at $y = -0.10$ m. What happens to the dipole?

A. It moves in the y direction but does not rotate.
B. It moves in the -y direction but does not rotate.
C. It rotates clockwise but does not move.
D. It rotates counterclockwise but does not move.
E. It does not rotate or move.

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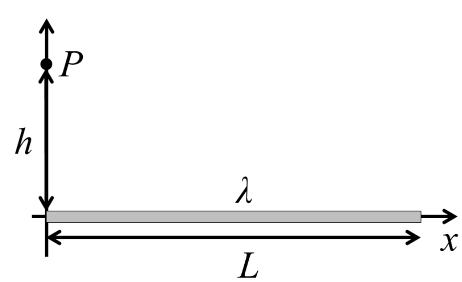
9) (5 pts) A thin rod of length L lays along the x-axis, as shown. The rod is uniformly charged with linear charge density λ. Consider a point P that is located a distance h from the origin on the y-axis. Which of these integrals could be evaluated to calculate the electric field in the y direction at point P?



A. $\int_0^L \frac{K\lambda L}{h^2} dx$
B. $\int_0^L \frac{K\lambda}{(x^2+h^2)} dx$
C. $\int_0^L \frac{K\lambda L}{(x^2+h^2)} dx$
D. $\int_0^L \frac{K\lambda h}{(x^2+h^2)^{3/2}} dx$
E. $\int_0^L \frac{K\lambda x}{(x^2+h^2)^{3/2}} dx$

II. Lab multiple choice (15 points)

10) (5 pts) In Lab A1, a student rubs a plastic rod with a cloth. The student then scrapes the rod across an initially uncharged metal sphere. The student rubs the rod again with the cloth. The rod is then brought close to the sphere without touching the sphere. Which of the following statements do you agree with?

    I. The rod and sphere have excess charge of the same type.
    II. Due to polarization of the sphere, the rod and sphere could attract one another.
    III. Due to the excess charge, the rod and sphere could repel one another.

A. I. only
B. III. only
C. I. and II. only
D. I. and III. only
E. All the statements.

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11) (5 pts) As part of Lab A2, a group measures the force exerted on a negative charge when it is placed 0.70 m from a positive charge. They carry out three trials and tabulate their data as shown. Which of the following best estimates of the force are consistent with the rules in this class:

Trial	Force (N)
1	2.41
2	2.48
3	2.38

    I. (2.42 ± 0.05) N
    II. (2.4 ± 0.05) N
    III. (2.423 ± 0.051) N

A. I. only
B. II. only
C. III. only
D. I. and II. only
E. I. and III. only

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12) (5 pts) A lab team is testing a model that relates quantities P and M as follows: $P = cM^2 + d$, where c and d are constants. The students measure the values of P as they vary M and they want to form a linearized graph to determine a value for the constant d. Which of the following should they carry out?

A. Plot P on the vertical axis, $\sqrt{M}$ on the horizontal axis and find the slope of the best-fit line.
B. Plot P on the vertical axis, $\sqrt{M}$ on the horizontal axis and find the *y*-intercept.
C. Plot M^2 on the vertical axis, P on the horizontal axis and find the slope of the best-fit line.
D. Plot P on the vertical axis, M^2 on the horizontal axis and find the *y*-intercept.
E. Plot $\sqrt{P}$ on the vertical axis, M on the horizontal axis and find the *x*-intercept.

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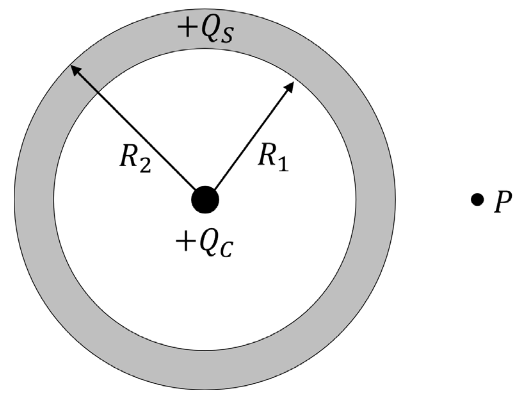
III. Lecture free response (25 points)

Consider a spherical metal shell with outer radius R_2 and inner radius R_1 as shown. A particle with charge $+Q_C$ is located at the center of the sphere, and the metal shell has a net excess charge of $+Q_s$.



13) (6 pts) How much excess charge is on the inner surface of the metal shell? Answer in terms of the given variables. Be sure to include the sign and explicitly state if it is zero. Explain your reasoning.

14) (5 pts) How much excess charge is on the outer surface of the metal shell? Answer in terms of the given variables. Be sure to include the sign and explicitly state if it is zero. Explain your reasoning.

15) (5 pts) Draw a Gaussian surface that allows you to determine the electric field at point P and explain why you chose this surface.

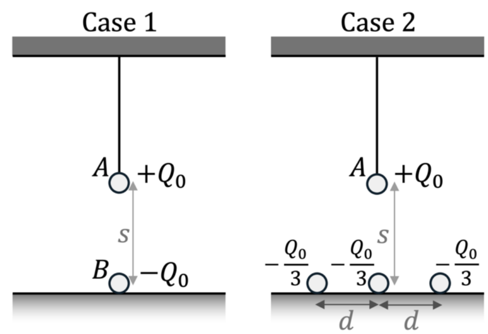
16) (3 pts) Write an expression for the area of your Gaussian surface. If your expression used any variables not already defined, be sure to indicate them on your drawing of the Gaussian surface.

17) (6 pts) Based on the Gaussian surface you drew, write an expression for the electric field at point P in terms of variables given, constants, and any variables you defined in question 16 above. Show your work and explain any assumptions.

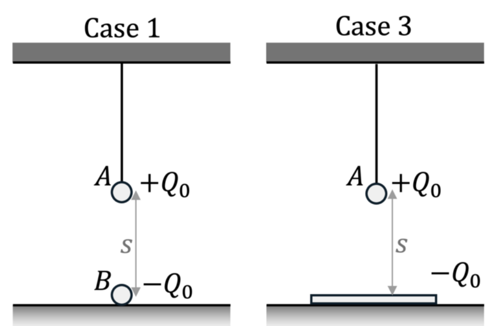
IV. Tutorial free response (15 points)

A small sphere, sphere A, with charge $+Q_0$is hung from a light inextensible string. In Case 1 a small sphere, sphere B, with charge $-Q_0$, is fixed to the ground directly below sphere A such that the distance between the centers of the spheres is s. The tension in the string is T_0.

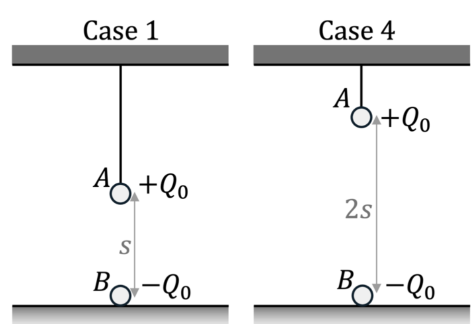
18) (5 pts) In case 2, sphere B from case 1 is replaced with three small spheres, each with charge $-Q_0/3$, and they are fixed to the locations shown. Is the magnitude of the tension in the string in case 2 *greater than*, *less than*, or *equal to* T_0? Explain your reasoning.



19) (5 pts) In case 3, sphere B from case 1 is replaced with an insulating rod with charge $-Q_0$ uniformly distributed along the rod. Is the magnitude of the tension in the string in case 3 *greater than*, *less than*, or *equal to* T_0? Explain your reasoning.



20) (5 pts) In case 1 it is known that the tension in the string, T_0, is twice the magnitude of the gravitational force exerted on sphere A. In case 4, the string attached to sphere A in case 1 is shortened such that the distance between the centers of the spheres is now $2s$. In case 4, what is the magnitude of the tension in the string in terms of T_0? Explain your reasoning.



Constants

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

Electrostatic constant $K = 8.99 \times 10^{9}\text{N·m}^2\text{C}^{-2}$

Permittivity constant $\epsilon_0 = \frac{1}{4\pi K} = 8.85 \times 10^{-12}\text{C}^2/(\text{N·m}^2)$

Mathematics

Vector components $\vec{A} = \vec{A}_x + \vec{A}_y = A_x\hat{\imath} + A_y\hat{\jmath}$

Vector magnitude $A = \sqrt{A_x^2 + A_y^2}$

θ ccw from x-axis $A_x = A\cos\theta$

$A_y = A\sin\theta$

$\theta = \tan^{-1}(A_y/A_x)$

Adding vectors $\vec{C} = \vec{A} + \vec{B}$ $C_x = A_x + B_x$

$C_y = A_y + B_y$

Dot product $\vec{A}\cdot\vec{B} = AB\cos\alpha$

$\vec{A}\cdot\vec{B} = A_xB_x + A_yB_y$

Cross product $|\vec{A}\times\vec{B}| = AB\sin\alpha$

$\vec{A}\times\vec{B} = -\vec{B}\times\vec{A}$

Area of sphere $4\pi r^2$

Volume of sphere $\frac{4}{3}\pi r^3$

Area of cylinder $2\pi(r^2 + rh)$

Volume of cylinder $\pi r^2 h$

Sample standard deviation $s = \sqrt{\frac{\sum_{i=1}^{n}(x_i - x_{\text{ave}})^2}{n-1}}$

Equations from 121

Constant acceleration (in "s" direction)

$v_{\text{fs}} = v_{\text{is}} + a_s\Delta t$

$s_{\text{f}} = s_{\text{i}} + v_{\text{is}}\Delta t + \frac{1}{2}a_s(\Delta t)^2$

$v_{\text{fs}}^2 = v_{\text{is}}^2 + 2a_s\Delta s$

Newton's 2nd law $\vec{a} = \frac{\vec{F}_{\text{net}}}{m}$

Newton's 3rd law $\vec{F}_{\text{A on B}} = -\vec{F}_{\text{B on A}}$

Kinetic energy $K = \frac{1}{2}mv^2$

Chapter 22

Coulomb's law $F_{1\text{ on }2} = F_{2\text{ on }1} = \frac{K|q_1||q_2|}{r^2}$

Force on q due to electric field $\vec{F}_{\text{on }q} = q\vec{E}$

Electric field due to point charge $\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r}$

Chapter 23

Superposition of electric fields $\vec{E}_{\text{net}} = \vec{E}_1 + \vec{E}_2 + \cdots$

Magnitude of electric dipole $p = qs$

Electric field due to an electric dipole:

- Along axis of the dipole $\vec{E}_{\text{dipole}} = \frac{1}{4\pi\epsilon_0}\frac{2\vec{p}}{r^3}$
- Perpendicular to the dipole $\vec{E}_{\text{dipole}} = -\frac{1}{4\pi\epsilon_0}\frac{\vec{p}}{r^3}$

Linear charge density $\lambda = \frac{Q}{L}$

Surface charge density $\eta = \frac{Q}{A}$

Electric field due to:

- line of charge $E_{\text{line}} = \frac{1}{4\pi\epsilon_0}\frac{2|\lambda|}{r}$
- ring of charge $E_{\text{ring}} = \frac{1}{4\pi\epsilon_0}\frac{zQ}{(z^2+R^2)^{3/2}}$
- disc of charge $E_{\text{disc}} = \frac{\eta}{2\epsilon_0}\left[1 - \frac{z}{\sqrt{z^2+R^2}}\right]$
- plane of charge $E_{\text{plane}} = \frac{\eta}{2\epsilon_0}$
- sphere of charge where $r > R$ $E_{\text{sphere}} = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}$
- between plates of parallel-plate cap. $E = \frac{Q}{\epsilon_0 A}$

Torque on electric dipole $\tau = pE\sin\theta$

Chapter 24

Electric flux through surface:

- Flat area and uniform field $\Phi_e = \vec{E}\cdot\vec{A} = EA\cos\theta$
- General $\Phi_e = \int_{\text{surface}}\vec{E}\cdot d\vec{A}$

Gauss's law $\Phi_e = \oint\vec{E}\cdot d\vec{A} = \frac{Q_{in}}{\epsilon_0}$