Physics 122 A
Autumn 2025

# 122A - N.TOLICH

Midterm 1
October $16^{th}$, 2025

**Please use the boxes below to clearly print your name and UW NetID.**
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**Clearly fill out this cover page and the top portion of the provided bubble sheet with the necessary information.**

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

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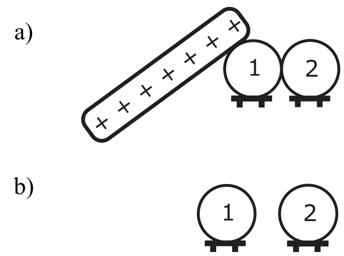
**I. Lecture multiple choice (45 points – 9 questions)**

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. 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) Consider two particles which have the same sign of charge. When the particles are separated by 10 cm the magnitude of the force between them is 1 µN. If the distance between the particles is reduced to 5 cm, which statement best describes the new force between the particles?

A. Repulsive and four times larger than the original force.
B. Repulsive and two times larger than the original force.
C. Repulsive and of equal magnitude to the original force.
D. Attractive and of equal magnitude to the original force.
E. Attractive and four times larger than the original force.

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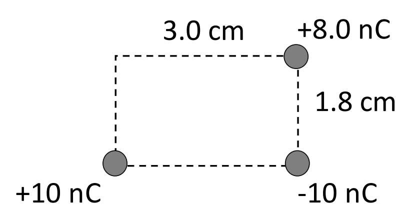
3) (5 pts) Three charged particles are located as shown. What is the magnitude of the net electric force on the 8.0 nC charge? Note that 1 nC = $10^{-9}$ C and 1 cm = $10^{-2}$ m.




A. $2.0 \times 10^{-3}$ N
B. $2.2 \times 10^{-3}$ N
C. $2.6 \times 10^{-3}$ N
D. $2.8 \times 10^{-3}$ N
E. $4.5 \times 10^{-3}$ N

4) (5 pts) Consider two charged particles, A and B. Particle A is located at the origin and has charge +1.0 nC. Particle B is located along the $x$-axis at $x = 1.8$ m and has charge +6.0 nC. At what location on the $x$-axis is the electric field created by the system of the two charges?

A. $x = 0.09$ m
B. $x = 0.13$ m
C. $x = 0.26$ m
D. $x = 0.52$ m
E. There is no location on the $x$-axis where the electric field is zero.

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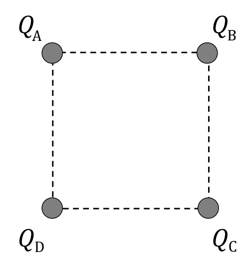
5) (5 pts) Four particles are located at the four corners of a square. The particles have charges, as shown. The electric field is measured to be **non-zero** at the center of the square. Which of the following charge configurations is possible?




A. $Q_A = q, Q_B = q, Q_C = q, Q_D = q$
B. $Q_A = q, Q_B = q, Q_C = 0, Q_D = 0$
C. $Q_A = q, Q_B = 0, Q_C = q, Q_D = 0$
D. $Q_A = q, Q_B = -q, Q_C = q, Q_D = -q$
E. More than one of the above answers is correct.

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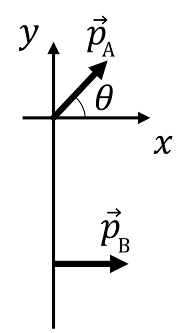
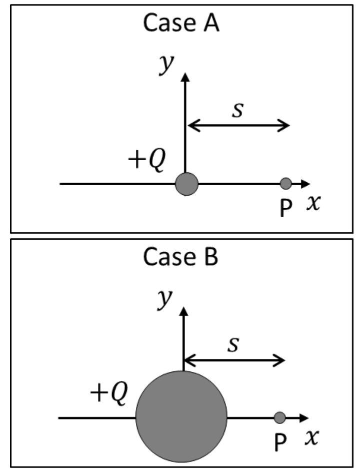
6) (5 pts) Consider two dipoles, A and B, as shown. Dipole A is located at the origin and has a dipole moment vector at an angle $\theta$ from the $x$-axis. Dipole B is located on the negative $y$-axis and has a dipole moment vector in the positive $x$ direction. At what angle $\theta$ will the magnitude of the torque on dipole A be maximized?




A. 0
B. $\frac{\pi}{4}$
C. $\frac{\pi}{3}$
D. $\frac{\pi}{2}$
E. $\pi$

7) (5 pts) Consider the two different charge distributions shown. In case A a particle with charge $+Q$ is placed at the origin. In case B a sphere with charge $+Q$ uniformly distributed on the surface is centered at the origin. Rank the magnitudes of the electric fields at point P in both cases.




A. $E_{\mathrm{A}} > E_{\mathrm{B}}$
B. $E_{\mathrm{A}} < E_{\mathrm{B}}$
C. $E_{\mathrm{A}} = E_{\mathrm{B}}$
D. More information is required.

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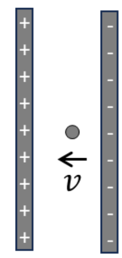
8) (5 pts) A parallel plate capacitor has positive charge on the left plate and negative charge on the right plate, as shown. A charged particle between the plates of the capacitor is moving to the left and <u>slowing down</u>. Which of the following statements about the electric field between the plates of the capacitor and the charge of the particle are true?




A. The electric field points to the <u>right</u>, and the particle is <u>positively</u> charged.
B. The electric field points to the <u>right</u>, and the particle is <u>negatively</u> charged.
C. The electric field points to the <u>left</u>, and the particle is <u>positively</u> charged.
D. The electric field points to the <u>left</u>, and the particle is <u>negatively</u> charged.
E. Not enough information is provided.

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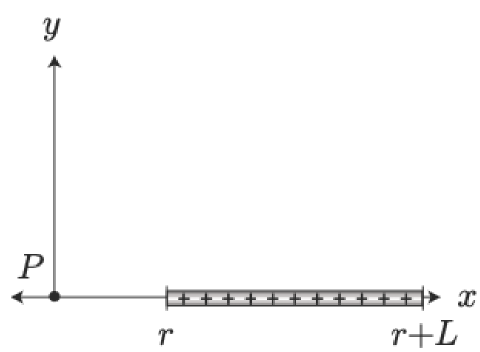
9) (5 pts) Consider a thin rod of length $L$ that lies between $r$ and $r + L$ along the $x$-axis, as shown. The rod is uniformly charged with linear charge density $\lambda$. Which of these integrals could be evaluated to calculate the electric field at the origin (point P)?




A. $\vec{E} = \frac{-\lambda\hat{\imath}}{4\pi\epsilon_0}\int_r^{L+r}\frac{1}{x^2}\,dx$

B. $\vec{E} = \frac{-\lambda\hat{\imath}}{4\pi\epsilon_0}\int_r^{L+r}\frac{y}{(y^2+(x-L)^2)^{3/2}}\,dx$

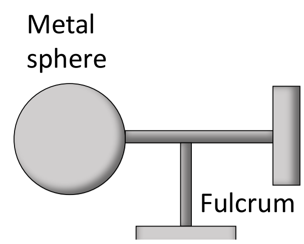
C. $\vec{E} = \frac{-\lambda\hat{\imath}}{4\pi\epsilon_0}\int_r^{L+r}\frac{x}{(y^2+(x-L)^2)^{3/2}}\,dx$

D. $\vec{E} = \frac{-\lambda\hat{\imath}}{4\pi\epsilon_0}\int_r^{L+r}\frac{1}{(x-L)^2}\,dx$

E. Not enough information given.

**II. Lab multiple choice (15 points)**

10) (5 pts) In lab A1 you placed an initially uncharged metal sphere on a fulcrum, as shown. You rubbed an acrylic rod with a wool cloth and then touched the acrylic rod to the metal sphere. You then rubbed the acrylic rod with the wool cloth again, before bringing the rod close to the metal sphere, without touching it. You observed that the metal sphere and the acrylic rod were initially repelled from each other, but as you brought the rod closer, they were attracted to each other. Which of the following explanations explains **all** your observations?




I. The rod and the sphere have opposite charges.
II. The rod and the sphere have the same charges.
III. The sphere gets less polarized the closer the rod gets.
IV. The sphere gets more polarized the closer the rod gets.

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

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11) (5 pts) As part of Lab A2, a group measure 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. Based on the rules for this course, how could they report the force?

| Trial | Force (N) |
| --- | --- |
| 1 | 15.63 |
| 2 | 15.78 |
| 3 | 15.43 |

A. 15.61 ± 0.05 N
B. 15.61 ± 0.01 N
C. 15.6 ± 0.18 N
D. 15.6 ± 0.2 N
E. 15.61 ± 0.2 N

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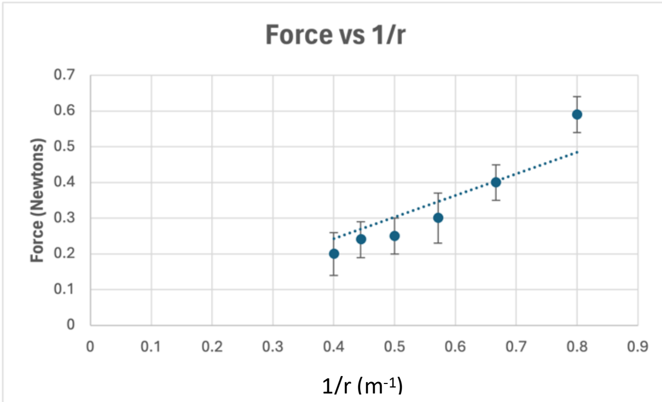
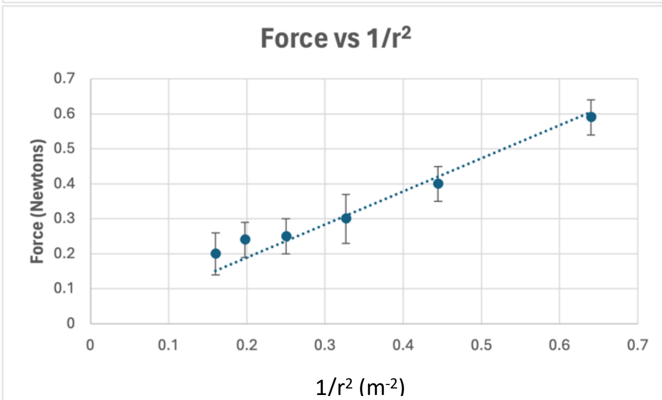
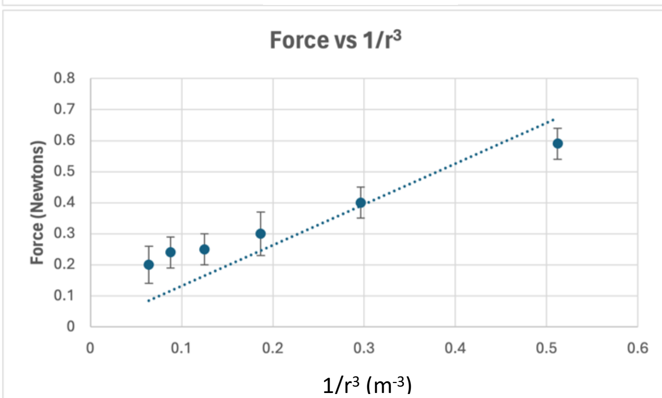
12) (5 pts) A student group does the VR experiment for Lab A2 to test three models for how force varies with charge separation. Based on their measurements they produce the following three graphs: $F$ *vs* $1/r$, $F$ *vs* $1/r^2$, and $F$ *vs* $1/r^3$.



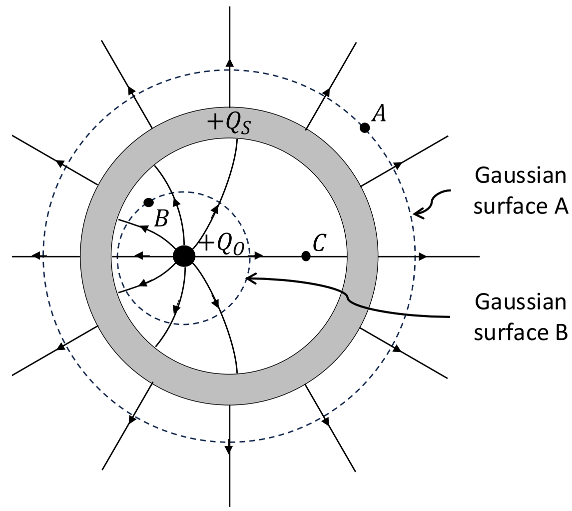




Which of the following is a reasonable conclusion based on the rules developed in this course?

A. Their results are consistent with only the model that $F = k/r$
B. Their results are consistent with only the model that $F = k/r^2$
C. Their results are consistent with only the model that $F = k/r^3$
D. Their results are consistent with both models: $F = k/r$ and $F = k/r^2$
E. Their results are consistent with all three models: $F = k/r$, $F = k/r^2$, and $F = k/r^3$

**III. Lecture free response (25 points)**

A spherical metal shell with outer radius $R_2$ and inner radius $R_1$ has a net excess charge of $+Q_S$. A particle with charge $+Q_O$ is located as shown. The figure also shows the electric field lines.




13) (5 pts) Rank the magnitudes of the electric fields at points A, B, and C. Explain your reasoning.

14) (3 pts) Write an algebraic expression for the electric flux through Gaussian surface A in terms of variables given above and constants.

15) (3 pts) Write an algebraic expression for the electric flux through Gaussian surface B in terms of variables given above and constants.

16) (5 pts) If $r_A$ is the radius of Gaussian surface A, and $E_A$ is magnitude of the electric field at point A, can the flux through Gaussian surface A be written as $4\pi r_A^2 E_A$? Explain your reasoning.

17) (5 pts) If $r_B$ is the radius of Gaussian surface B, and $E_B$ is magnitude of the electric field at point B, can the flux through Gaussian surface B be written as $4\pi r_B^2 E_B$? Explain your reasoning.

18) (4 pts) If you ground the outside of the metal sphere by briefly touching it, what would be the net charge on the metal sphere after you are no longer touching it?

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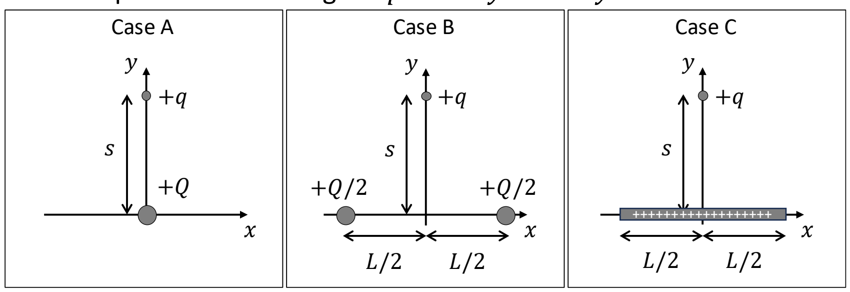
**IV. Tutorial free response (15 points)**

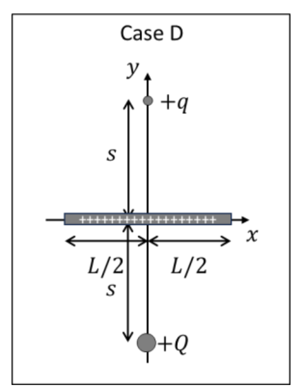
Consider the three different charge distributions shown. Case A has a particle of charge $+Q$ at the origin. Case B has two particles of charge $+Q/2$, one located at $x = -L/2$ and the other at $x = L/2$. Case C has a thin rod between $x = -L/2$ and $x = L/2$ with charge $+Q$ uniformly distributed along the rod. In all cases there is a particle with charge $+q$ on the $y$-axis at $y = s$.




19) (5 pts) Compare the magnitude of the net electric force on the +$q$ charge in cases A and B. <u>Explain your reasoning.</u>

20) (5 pts) Compare the magnitude of the net electric force on the +$q$ charge in cases B and C. <u>Explain your reasoning.</u>

21) (5 pts) Now consider case D, which is similar to case C, except another particle with charge $+Q$ is added on the $y$-axis at $y = -s$. Compare the magnitude of the net electric force on the +$q$ charge in cases C and D. <u>Explain your reasoning.</u>



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

Permeability constant $\mu_0 = 1.26 \times 10^{-6}\text{T·m/A}$

Speed of light $c = 3.0 \times 10^{8}\text{m/s}$

## Mathematics

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

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

$\theta$ 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 $\Phi_{\text{e}} = \vec{E}\cdot\vec{A} = EA\cos\theta$
- General $\Phi_{\text{e}} = \int_{\text{surface}}\vec{E}\cdot d\vec{A}$

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