Physics 122 A
Winter 2025

122A - N.TOLICH

Midterm 2
February 20th, 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.

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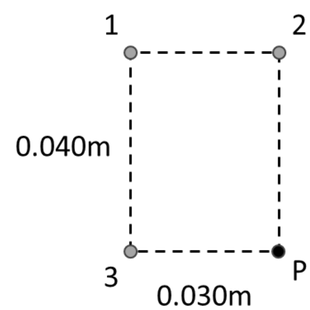
I. Lecture multiple choice (45 points – 9 questions)

1) (5 pts) Consider two different cases where an insulating sphere has positive charge uniformly distributed on the surface. In case A the sphere has radius R_A and net charge Q_A. In case B the sphere has radius $R_B = 2R_A$ and net charge $Q_B = 2Q_A$. Compare the potential at the surface of the spheres in each case.

   A. $V_A > V_B$
   B. $V_A < V_B$
   C. $V_A = V_B$
   D. There is not enough information to tell.

Use the following setup for the next two questions.



Three particles, 1, 2, and 3, are placed at the corners of a rectangle as shown on the right. The charge of particle 1 is 3.0×10^{-9} C, and the charges of particles 2 and 3 are each -3.0×10^{-9} C.

2) (5 pts) What is the electric potential at position P?

   A. 2.4×10^4 V
   B. 2.1×10^3 V
   C. -1.0×10^3 V
   D. -2.4×10^4 V
   E. -3.6×10^4 V

3) (5 pts) If particle 2 were removed, would the potential energy of the system of particles *increase*, *decrease*, or *remain the same*?

   A. Increase
   B. Decrease
   C. Remain the same
   D. There is not enough information to tell.

4) (5 pts) A parallel-plate capacitor with plates separated by distance d is fully charged by a battery. While it is still **connected** to the battery, the plates are then pushed together until they are separated by a distance $0.5d$. If the initial potential energy stored in the capacitor is U_i, what is the final potential energy stored in the capacitor?

A. $\frac{1}{4}U_i$
B. $\frac{1}{2}U_i$
C. U_i
D. $2U_i$
E. $4U_i$

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5) (5 pts) In a cubical region of space that is 0.015 m by 0.015 m by 0.015 m the electric field is uniform and 7.0×10^{-11} J of energy is stored in the field. What is the electric field strength in this region?

A. 7.3×10^{-3} V/m
B. 2.8×10^{0} V/m
C. 4.0×10^{0} V/m
D. 1.5×10^{3} V/m
E. 2.2×10^{3} V/m

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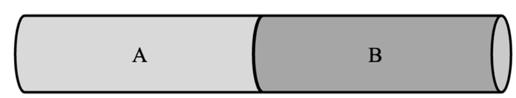
6) (5 pts) Two wires with the same cross-sectional areas and lengths but made of materials with different conductivities are connected as shown. The combination is connected to a battery. Which of the following are **the same** for both wires?



i. Current
ii. Current density
iii. Electric field

A. i. and ii.
B. i. and iii.
C. ii. and iii.
D. All of them.
E. None of them.

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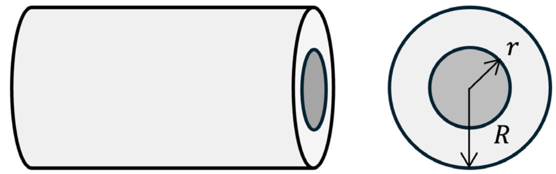
7) (5 pts) A wire of radius $R = 0.002$ m carries current $I = 0.20$ A. How many electrons pass through the surface of radius $r = 0.001$ m in each second? Assume that the current is uniformly distributed across the cross-sectional area.



A. 5.0×10^2
B. 1.2×10^{14}
C. 3.1×10^{17}
D. 6.2×10^{17}
E. 1.2×10^{18}

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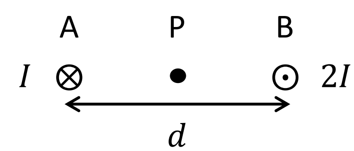
8) (5 pts) Two wires a distance $d = 0.02$ m apart carry current perpendicular to the page. Wire A carries current $I = 0.2$ A into the page, wire B carries current $2I$ out of the page. What is the magnitude of the magnetic field at point P, <u>midway</u> between the two wires?



A. There is no magnetic field at point P
B. $\frac{\mu_0 I}{2\pi d}$
C. $\frac{\mu_0 I}{\pi d}$
D. $\frac{3\mu_0 I}{2\pi d}$
E. $\frac{3\mu_0 I}{\pi d}$

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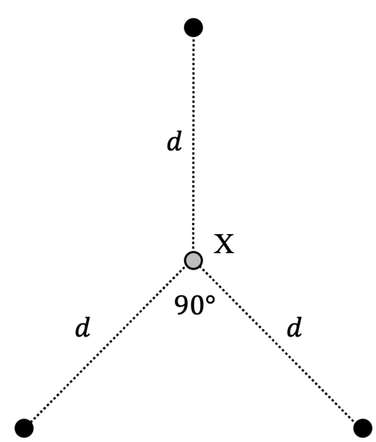
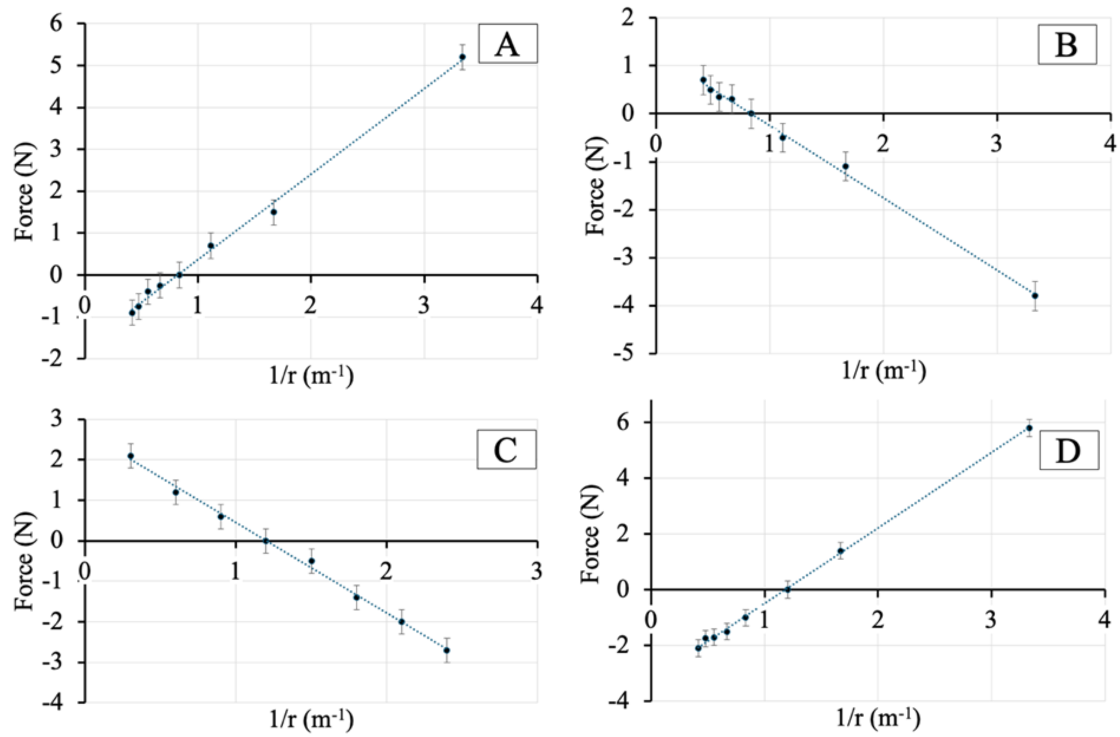
9) (5 pts) Three wires carry current I out of the page. Point X is a distance d from all three wires, as shown. What is the direction of the magnetic field at point X?



A. There is no magnetic field at point X
B. To the left
C. To the right
D. Toward the top of the page
E. Some other direction

II. Lab multiple choice (15 points)

10) (5 pts) In Lab A3, students measured the force, F, on a minty particle, while varying the distance, r, from another minty particle. Starting at a separation of 0.30 m, they increased the distance in 0.30 m steps up to 2.4 m. They observed that the particles repelled each other when $r < 1.2$ m, and attracted each other when $r > 1.2$ m. The students defined a positive reading on their force meter as an attractive force and a negative reading as a repulsive force. They notice that an F versus $1/r$ produces a linearized graph. Which graph (A to D) below is consistent with this description?



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11) (5 pts) In Lab A4, students take three force measurements between two exotic particles. The force measurement device is a digital scale that reads to one-hundredth of a newton. Their measurements are shown at right. If σ_r represents the random uncertainty and σ_i represents the instrumental uncertainty, what is the ratio σ_r/σ_i?

Trial	Force (N)
1	0.52
2	0.57
3	0.61

A. 2
B. 5
C. 9
D. 11
E. 14

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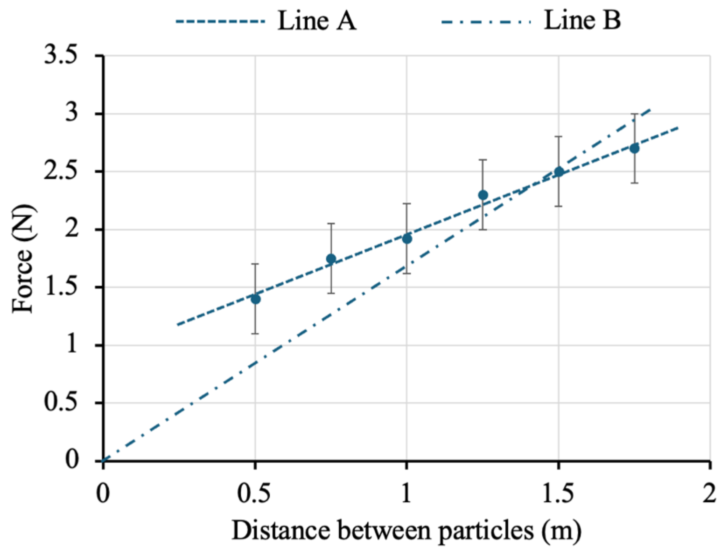
12) (5 pts) In a lab similar to Lab A4, a lab team explores the forces exerted between two exotic particles in a VR simulation. They make a plot of the force versus the distance between the two particles, as shown at right, and draw two best-fit lines, line A and line B. Note that line B passes through the origin. Which of the following statements is true, based on the rules stated in this course?



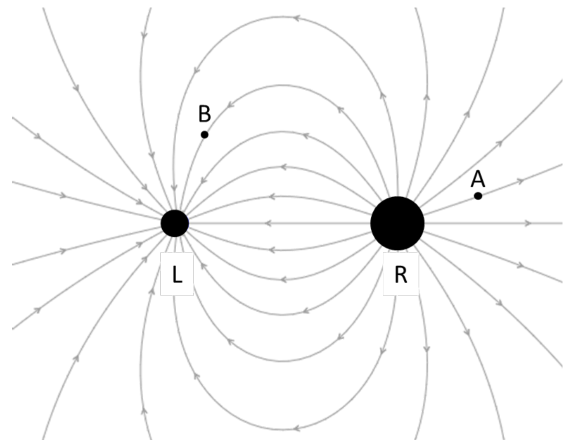
i. Their data is consistent with a model represented by line A.
ii. Their data is consistent with a model represented by line B.
iii. With line A you could test a model that the force is *proportional* to the distance between the particles.
iv. With line B you could test a model that the force is *proportional* to the distance between the particles.

A. i. only
B. i. and iii.
C. i. and iv.
D. i., ii., and iv.
E. i., iii., and iv.

III. Lecture free response (25 points)

For all the lecture free response questions assume that the electric potential is zero at infinity.

Consider two solid metal spheres, as shown. The left sphere has radius R_0 and net charge $-Q_0$. The right sphere has radius $2R_0$ and net charge $+Q_0$. The electric field lines are shown. The potential at the surface of the left sphere is V_{L} and the potential at the surface of the right sphere is V_{R}.



13) (6 pts) Sketch **two** equipotential surfaces; one that passes through point A, and one that passes through point B.

14) (7 pts) What is the capacitance for this charge configuration? Write an expression in terms of variables given and constants.

15) (7 pts) A new particle with mass m_p and charge $+q_{\mathrm{p}}$ is added to the system. The new particle is initially at the surface of the left sphere and moving towards the right sphere with speed v. What is the minimum speed the particle must have if it is to reach the right sphere without turning around? Write an expression in terms of variables given and constants. Show your work.

Now a conducting wire is connected between the two spheres.

16) (5 pts) When electrostatic equilibrium is reached, what is the potential at the surface of the left sphere? Write an expression in terms of variables given and constants. Explain your reasoning.

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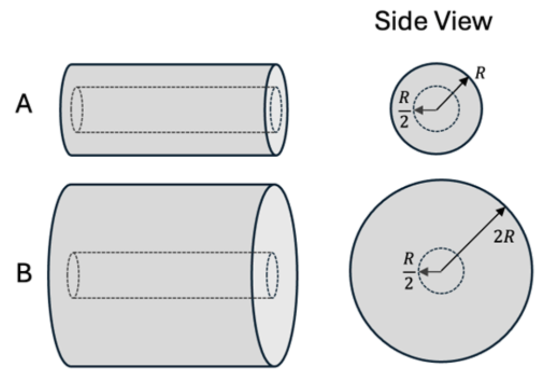
IV. Tutorial free response (15 points)

The diagram at right shows two very long, solid non-conducting cylinders, cylinder A with radius R and cylinder B with radius $2R$. Each cylinder carries a total positive charge $+Q$ uniformly spread throughout their volumes. Each cylinder also has an imaginary Gaussian surface, a coaxial cylinder of radius $\frac{R}{2}$ and length L, centered inside.



17) (3 pts) Is the volume charge density for cylinder A *greater than, less than,* or *equal to* the volume charge density for cylinder B? Explain your reasoning.

18) (4 pts) Is the net electric flux through the Gaussian surface within cylinder A *greater than, less than,* or *equal to* the net electric flux through the Gaussian surface within cylinder B? Explain your reasoning.

An electron is present in a unform horizontal electric field. The field lines are shown in the figure, but the direction of the field is not shown. At point *A*, the electron has a speed v_A and is moving to the left. At point *B*, the electron has a speed v_B, where $v_B < v_A$. No forces other than the electric force act on the electron.

19) (4 pts) What is the direction of the electric field? Explain your reasoning.

20) (4 pts) Is the value of $V_B - V_A$ positive, negative or zero? Explain your reasoning.

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

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

Chapter 25

Potential energy in configuration of

charge between plates of a parallel-plate capacitor $U_{\text{elec}} = qEs$

two point charges $U_{\text{elec}} = \frac{Kq_1q_2}{r}$

dipole in uniform electric field

$$U_{\text{elec}} = -pE\cos\phi = -\vec{p}\cdot\vec{E}$$

Potential energy from potential $U_{\text{elec}} = qV$

Electric potential ($V = 0$ at infinity) due to:

point charge $V_{\text{point}} = \frac{Kq}{r}$

sphere of charge where $r \geq R$ $V_{\text{sphere}} = \frac{KQ}{r}$

ring of charge $V_{\text{ring on axis}} = \frac{KQ}{\sqrt{R^2+z^2}}$

disk $V_{\text{disk on axis}} = \frac{2KQ}{R^2}\left(\sqrt{z^2+R^2} - |z|\right)$

Chapter 26

Potential difference $\Delta V = V_{\text{f}} - V_{\text{i}} = -\int_{\text{i}}^{\text{f}} \vec{E}\cdot d\vec{s}$

Electric field in s direction $E_s = -\frac{dV}{ds}$

Electric field vector $\vec{E} = -\left(\frac{\partial V}{\partial x}\hat{\imath} + \frac{\partial V}{\partial y}\hat{\jmath} + \frac{\partial V}{\partial z}\hat{k}\right)$

Emf $\mathcal{E} = \frac{W_{\text{chem}}}{q}$

Ideal battery $\Delta V_{\text{bat}} = \mathcal{E}$

Charge on a capacitor $Q = C\Delta V_C$

Capacitance of parallel-plate capacitor $C = \frac{\epsilon_0 A}{d}$

Capacitors in parallel $C_{\text{eq}} = C_1 + C_2 + C_3 + \cdots$

Capacitors in series $C_{\text{eq}} = \left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots\right)^{-1}$

Capacitor potential energy $U_C = \frac{Q^2}{2C} = \frac{1}{2}Q\Delta V_C = \frac{1}{2}C(\Delta V_C)^2$

Energy density of electric field $u_{\text{E}} = \frac{1}{2}\epsilon_0 E^2$

Dielectric constant $\kappa = \frac{E_0}{E}$

Capacitance with dielectric $C = \kappa C_0$

Induced charge density $\eta_{\text{induced}} = \eta_0\left(1 - \frac{1}{\kappa}\right)$

Chapter 27

Electron current in wire $i_{\text{e}} = n_{\text{e}}Av_{\text{d}}$

Current $I = \frac{dQ}{dt}$

Current density $J = \frac{I}{A}$

Kirchoff's junction law $\sum I_{\text{in}} = \sum I_{\text{out}}$

Current density $J = \sigma E$

Conductivity $\sigma = \frac{n_{\text{e}}e^2\tau}{m}$

Resistivity $\rho = \frac{1}{\sigma}$

Resistance $R = \frac{\rho L}{A}$

Ohm's law $I = \frac{\Delta V}{R}$

Chapter 29

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

Magnetic field of

point charge $\vec{B}_{\text{point charge}} = \frac{\mu_0}{4\pi}\frac{q\vec{v}\times\hat{r}}{r^2}$

current segment $\vec{B}_{\text{current segment}} = \frac{\mu_0}{4\pi}\frac{I\Delta\vec{s}\times\hat{r}}{r^2}$

long straight wire $B_{\text{wire}} = \frac{\mu_0}{2\pi}\frac{I}{r}$

N-turn current loop $B_{\text{coil center}} = \frac{\mu_0}{2}\frac{NI}{R}$