Physics 122 A
Autumn 2025

122A - N.TOLICH

Midterm 2
November 6^{th}, 2025

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

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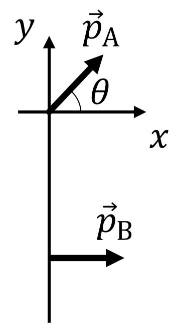
I. Lecture multiple choice (45 points – 9 questions)

1) (5 pts) Consider two dipoles, A and B, as shown. Dipole A is located at the origin and has a dipole moment vector at an angle θ from the x-axis. Dipole B is located on the negative y-axis and has a dipole moment vector in the positive x direction. What angle θ will minimize the potential energy of the system of both dipoles?



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

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2) (5 pts) An electron initially at rest accelerates through a potential difference of 800 V. What is the speed of the electron after this acceleration?
Note that the electron mass is 9.11×10^{-31} kg.

A. 1.82×10^{7} m/s
B. 1.68×10^{7} m/s
C. 1.43×10^{7} m/s
D. 1.23×10^{7} m/s
E. 1.07×10^{7} m/s

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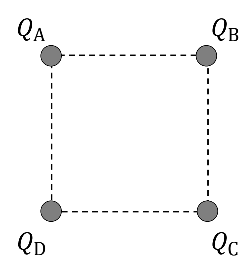
3) (5 pts) Four particles are located at the four corners of a square. The particles have charges, as shown. The electric potential is measured to be **<u>zero</u>** at the center of the square. Which of the following charge configurations is possible?
Note that the potential at infinity is zero.



A. $Q_{\mathrm{A}} = q, Q_{\mathrm{B}} = q, Q_{\mathrm{C}} = q, Q_{\mathrm{D}} = q$
B. $Q_{\mathrm{A}} = q, Q_{\mathrm{B}} = q, Q_{\mathrm{C}} = 0, Q_{\mathrm{D}} = 0$
C. $Q_{\mathrm{A}} = q, Q_{\mathrm{B}} = 0, Q_{\mathrm{C}} = q, Q_{\mathrm{D}} = 0$
D. $Q_{\mathrm{A}} = q, Q_{\mathrm{B}} = -q, Q_{\mathrm{C}} = q, Q_{\mathrm{D}} = -q$
E. More than one of the above answers is correct.

4) (5 pts) You want to store 2.5 J of energy in a capacitor with a capacitance of 20 μF. What potential difference do you need to apply between the electrodes?
Note that 1 μF = 10^{-6} F

A. 250 V
B. 354 V
C. 500 V
D. 707 V
E. 1500 V

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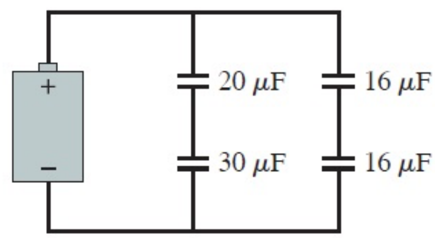
5) (5 pts) Consider the four capacitors arranged as shown in the figure on the right. What is the equivalent capacitance?



A. 0.21 μF
B. 20 μF
C. 36 μF
D. 44 μF
E. 76 μF

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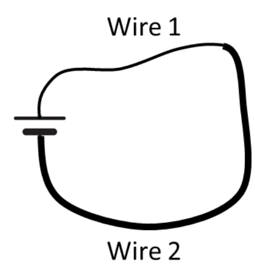
6) (5 pts) Consider a circuit made with two different long wires with circular cross-sections. The wires are connected in **series** to a battery. The table below shows the properties of the two wires.

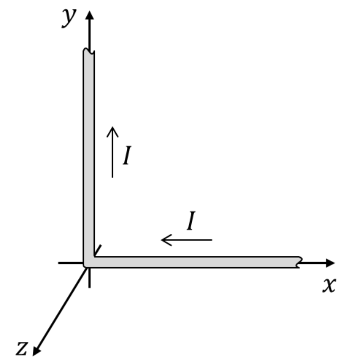


	Wire 1	**Wire 2**
Length	L	$2L$
Cross-sectional radius	r	$2r$
Resistivity	ρ	2ρ

What is the relationship between the magnitudes of the electric fields in wire 1, E_1, and wire 2, E_2? Assume the current is uniform over the cross-section of the wires.

A. $E_2 = E_1 = 0$
B. $E_2 = \frac{1}{8}E_1$
C. $E_2 = \frac{1}{4}E_1$
D. $E_2 = \frac{1}{2}E_1$
E. $E_2 = 2E_1$

7) (5 pts) An infinitely long wire carries current I and is bent at 90° with the bend at the origin of a co-ordinate system, as shown. Which one of the following expressions allows you to determine the magnetic field at the origin?



A. $\vec{B} = \frac{\mu_0 I}{4\pi}\left[\hat{\imath}\int_\infty^0 \frac{dx}{x^2} + \hat{\jmath}\int_0^\infty \frac{dy}{y^2}\right]$
B. $\vec{B} = \frac{\mu_0 I}{4\pi}\left[-\hat{\imath}\int_\infty^0 \frac{dx}{x^2} + \hat{\jmath}\int_0^\infty \frac{dy}{y^2}\right]$
C. $\vec{B} = \frac{\mu_0 I}{4\pi}\left[\hat{k}\int_\infty^0 \frac{dx}{x^2} + \hat{k}\int_0^\infty \frac{dy}{y^2}\right]$
D. $\vec{B} = \frac{\mu_0 I}{4\pi}\left[\hat{k}\int_\infty^0 \frac{dx}{x^2} - \hat{k}\int_0^\infty \frac{dy}{y^2}\right]$
E. $\vec{B} = \vec{0}$

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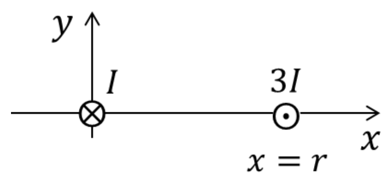
8) (5 pts) Consider two infinite wires, as shown to the right. Wire 1 is at the origin and carries current I into the page, and wire 2 is on the x-axis at $x = r$ and carries current $3I$ out of the page. At what point along the x-axis will the magnitude of the magnetic field be zero?



A. $x = -r/2$
B. $x = -r/3$
C. $x = +r/\sqrt{2}$
D. $x = +r/\sqrt{3}$
E. There is nowhere on the x-axis where the field is zero.

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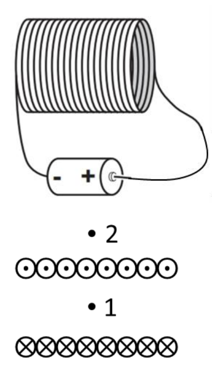
9) (5 pts) Consider a finite length solenoid connected to a battery as shown at the top right. The image at bottom right shows a slice along the length of the solenoid showing that the wires at the top have current flowing out of the page, and the wires at the bottom have current flowing into the page. Which one of the following statements about the magnetic field at points 1 and 2 is correct? The magnitude of the magnetic fields at points 1 and 2 are B_1 and B_2, respectively.



A. $B_1 < B_2$, and the magnetic field at point 1 is to the left.
B. $B_1 > B_2$, and the magnetic field at point 1 is to the left.
C. $B_1 < B_2$, and the magnetic field at point 1 is to the right.
D. $B_1 > B_2$, and the magnetic field at point 1 is to the right.
E. $B_1 = B_2$, and the magnetic field at point 1 is to the right.

II. Lab multiple choice (15 points)

10) (5 pts) In Lab A3 a team placed two minty particles in their VR simulation and observed that the distance between them oscillated, coming close and then moving away repeatedly. They then measured the force on a minty charged particle, F, while varying the distance, d, to another minty particle. They measured positive forces for distances less than 0.5 m and negative forces for distances greater than 0.5 m. Based on their observations and measurements, which one of the following statements is true?

    A. Positive force is attractive.
    B. Negative force is attractive.
    C. Their force measurements are not consistent with their observations, so they must have made a mistake.
    D. Not enough information is provided.

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11) (5 pts) In Lab A4 a team explored how many different types of particles are in their VR simulation. They spawned five particles and gave them all different colors. Then in pairs they placed the particles 1 m away from each other and determined if the force is attractive (A), repulsive (R), or no force (N). They obtained the following table.

	Blue	Orange	Green	Red	Purple
Blue		N	A	A	N
Orange	N		R	N	A
Green	A	R		A	R
Red	A	N	A		N
Purple	N	A	R	N	

Which of the following conclusions is consistent with their data?

I. Blue and Red are the same type of particle
II. Green and Orange are the same type of particle
III. Orange and Purple are the same type of particle

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

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12) (5 pts) In the VR simulation each member of a team measures the force on a particle, and they obtain the following results: 0.56 N, 0.56 N, 0.56 N, and 0.56 N. Based on the rules for this course, which one of the following statements is most correct?

    A. There is no uncertainty in their measurements.
    B. There is a random uncertainty of 0.005 N.
    C. There is an instrumental uncertainty of 0.005 N.

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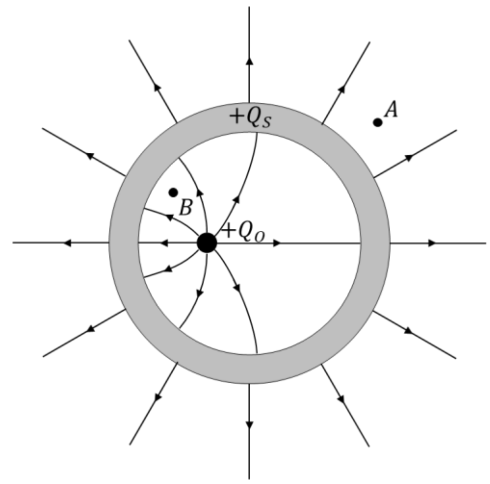
III. Lecture free response (25 points)

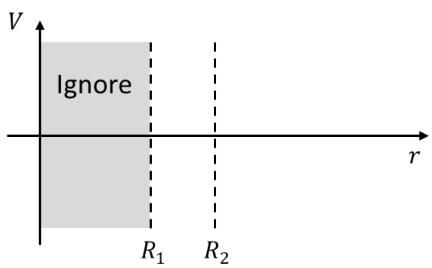
A spherical metal shell with outer radius R_2 and inner radius R_1 has a net excess charge of $+Q_s$. A particle with charge $+Q_O$ is located as shown. The figure also shows the electric field lines. Assume that the electric potential at infinity is zero.



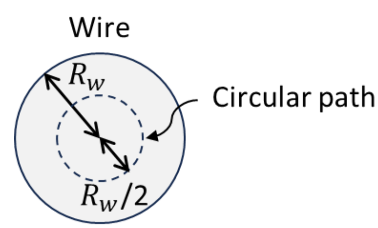
13) (5 pts) Sketch **<u>two</u>** equipotential surfaces; <u>one that passes through point A, and one that passes through point B</u>.

14) (5 pts) Is the electric potential at point A, V_{A}, *greater than*, *less than*, or *equal to* the potential at point B, V_{A}? <u>Explain your reasoning.</u>

15) (5 pts) On the graph below sketch the electric potential as a function of the distance from the center of the spherical metal shell, ignoring the region with radius less than R_1.



Consider an infinitely long wire with a circular cross-section of radius R_w, as shown at the right. The wire carries current I_w out of the page. Assume that the current is uniform across the wire's circular cross section.

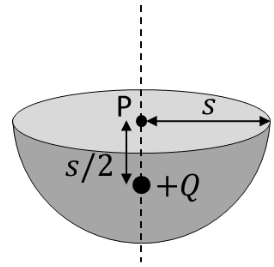


16) (5 pts) Consider a closed circular path of radius $R_w/2$ as shown. Using variables given above and constants, derive an algebraic expression for $\oint \vec{B} \cdot d\vec{s}$ around the path. <u>Show your work.</u>

17) (5 pts) Using variables given above and constants, derive an algebraic expression for the magnitude of the magnetic field at a distance $R_w/2$ from the center of the wire. <u>Show your work.</u>

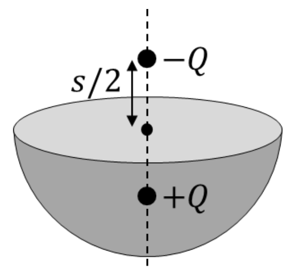
IV. Tutorial free response (15 points)

Consider a hemispherical (half sphere) Gaussian surface with radius s, as shown at right. A particle with charge $+Q$ is located a distance $s/2$ directly below point P, which is at the center of the flat surface of the Gaussian surface. The magnitude of the electric field at point P is E_{P}.

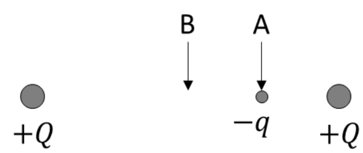


18) (5 pts) Is the flux through the flat circular surface of the Gaussian surface *greater than*, *less than*, or *equal to* $E_{\mathrm{P}}\pi s^2$? Explain your reasoning.

19) (5 pts) Now a particle with charge $-Q$ is added a distance $s/2$ directly above point P, as shown at right. When the new particle is added, does the electric flux through the curved surface of the Gaussian surface *increase*, *decrease*, or *remain the same*? Explain your reasoning.



Two particles, each with charge $+Q$ are fixed in place as shown at right. A third particle with charge $-q$ is moved in a controlled fashion such that it starts at rest at point A, and ends at rest at point B, which is midway between the other charges.



20) (5 pts) Is $V_{\mathrm{B}} - V_{\mathrm{A}}$ *greater than*, *less than*, or *equal to* zero? Explain your reasoning.

Constants

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

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

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

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

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

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 $\Phi_{\text{e}} = \vec{E}\cdot\vec{A} = EA\cos\theta$

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

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

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 $B_{\text{coil center}} = \frac{\mu_0}{2}\frac{NI}{R}$

Magnetic dipole magnitude $m = AI$

Magnetic field due to dipole on axis $\vec{B}_{\text{dipole}} = \frac{\mu_0}{4\pi}\frac{2\vec{m}}{z^3}$

Ampère's law $\oint \vec{B}\cdot d\vec{s} = \mu_0 I_{\text{through}}$

Magnetic field due to solenoid $B = \mu_0 nI$

Force on moving charge in B field $F_{\text{on q}} = |q|vB\sin\alpha$

Force on moving charge in B field $\vec{F}_{\text{on q}} = q\vec{v}\times\vec{B}$

Force on wire in B field $F_{\text{wire}} = IlB\sin\alpha$

Force on wire in B field $\vec{F}_{\text{wire}} = I\vec{l}\times\vec{B}$

Radius of cyclotron orbit $r_{\text{cyc}} = \frac{mv}{|q|B}$

Torque on magnetic dipole in B field $\vec{\tau} = \vec{m}\times\vec{B}$