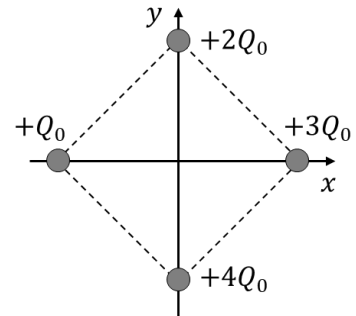


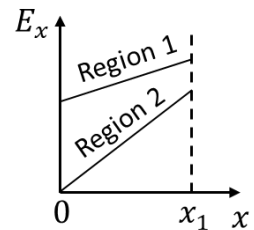
I. Lecture multiple choice (45 points – 9 questions)

- 1) (5 pts) Four point particles are fixed at the corners of a $0.010\text{m} \times 0.010\text{m}$ square, as shown. The electric potential at infinity is zero and $Q_0 = 1.2 \times 10^{-9}\text{C}$. Find the electric potential at the origin $(x, y) = (0, 0)$.



- A. $V(0,0) = 3.1 \times 10^3 \text{ V}$
- B. $V(0,0) = 4.3 \times 10^3 \text{ V}$
- C. $V(0,0) = 6.1 \times 10^3 \text{ V}$
- D. $V(0,0) = 1.1 \times 10^4 \text{ V}$
- E. $V(0,0) = 1.5 \times 10^4 \text{ V}$

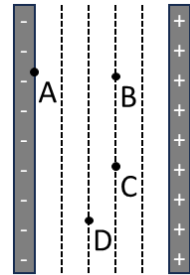
- 2) (5 pts) The electric field is measured in two regions of space, 1 and 2. For both regions the graph on the right shows the x component of the electric field, E_x , as a function of x from 0 to x_1 . Consider the absolute value of the change in electric **potential** between $x = 0$ and x_1 for region 1, $|\Delta V_1|$, and region 2, $|\Delta V_2|$. Which one of the following statements is correct?



- A. $|\Delta V_1| < |\Delta V_2|$ because E_x changes at a greater rate with respect to x in region 2.
- B. $|\Delta V_1| < |\Delta V_2|$ because E_x is smaller at the origin in region 2.
- C. $|\Delta V_1| > |\Delta V_2|$ because E_x changes at a smaller rate with respect to x in region 1.
- D. $|\Delta V_1| > |\Delta V_2|$ because the area under the E_x versus x curve between $x = 0$ and x_1 is greater in region 1.
- E. We can't compare $|\Delta V_1|$ and $|\Delta V_2|$ unless we know the values of the field and the positions

- 3) (5 pts) Consider the following two scenarios where a single capacitor is connected to a single battery: capacitor A is connected to battery A, and capacitor B is connected to battery B. The capacitance of capacitor A is smaller than the capacitance of capacitor B by a factor of 0.6. The emf of battery A is greater than the emf of battery B by a factor of 1.2. Compare the energy stored in capacitor A, U_A , to the energy stored in capacitor B, U_B . Which one of the following statements is correct?
- A. $U_A > U_B$ because battery A has a greater emf.
 - B. $U_A < U_B$ because capacitor B has a greater capacitance.
 - C. $U_A = U_B$ because the greater emf of battery A cancels out the smaller capacitance of capacitor A.
 - D. $U_A > U_B$ because the greater emf of battery A more than compensates for smaller capacitance of capacitor A.
 - E. $U_A < U_B$ because the greater capacitance of capacitor B more than compensates for the smaller emf of battery B.

- 4) (5 pts) A particle in a parallel plate capacitor is moved from positions A to B to C to D. The equipotential lines are shown on the diagram. Which of the following correctly represents the electric potential difference between points A and D, ΔV_{AD} ? Note that the notation ΔV_{AD} represents $V_D - V_A$.



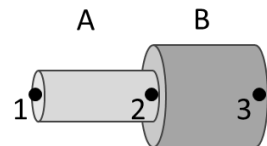
- A. $\Delta V_{AD} = \Delta V_{AB} + \Delta V_{BC} - \Delta V_{CD}$
- B. $\Delta V_{AD} = \Delta V_{AB} - \Delta V_{BC} - \Delta V_{CD}$
- C. $\Delta V_{AD} = \Delta V_{AB} + \Delta V_{CD}$
- D. $\Delta V_{AD} = \Delta V_{AB} - \Delta V_{CD}$
- E. The correct choice would depend on the sign of the charge that is being moved.

- 5) (5 pts) A parallel-plate capacitor is connected to a battery, fully charged, and then the battery is **disconnected**. A dielectric is then inserted between the plates of the capacitor while the separation distance of the plates remains fixed. Comparing the initial state without the dielectric to the state after the dielectric is inserted, which one of the following correctly describes the resulting changes, if any, to the absolute value of the charge on the plates, Q_o , and the absolute value potential difference across the capacitor, V_{cap} ?
- A. Both Q_o and V_{cap} stay the same.
 - B. Both Q_o and V_{cap} decrease.
 - C. Q_o increases and V_{cap} stays the same.
 - D. Q_o decreases and V_{cap} increases.
 - E. Q_o stays the same and V_{cap} decreases.

6) (5 pts) A wire of cross-sectional area $A = 4.5 \times 10^{-6} \text{ m}^2$, length $L = 0.30 \text{ m}$, and resistivity $\rho = 3.4 \times 10^{-8} \Omega \cdot \text{m}$ carries current $I = 12 \text{ A}$ along it. What is the potential difference between the ends of the wire?

- A. $\Delta V = 1.6 \times 10^{-5} \text{ V}$
- B. $\Delta V = 2.7 \times 10^{-2} \text{ V}$
- C. $\Delta V = 1.0 \times 10^{-4} \text{ V}$
- D. $\Delta V = 37 \text{ V}$
- E. None of the above

7) (5 pts) Two wires, A and B, have equal length but with different radii, and are made of metals with different resistivities. Wires A and B are connected as shown, and one side of a battery is connected to point 1 (the left of wire A), and the other side of the battery is connected to point 3 (the right of wire B). Point 2 is where wires A and B are connected. The electrical potential difference across wire A, ΔV_{12} , is greater than that across wire B, ΔV_{23} . Consider the following statements comparing the current densities, J , currents, I , and electric fields, E , in wires A and B:

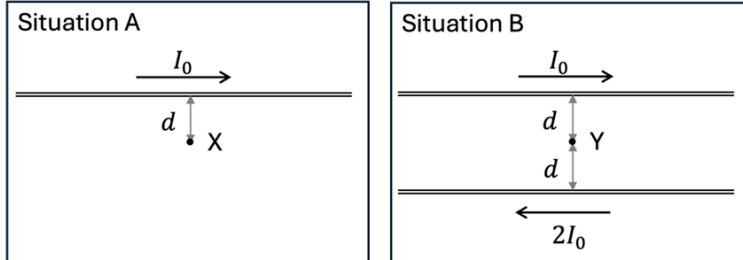


- i. $J_A = J_B$
- ii. $I_A = I_B$
- iii. $E_A = E_B$

Which of these statements are correct?

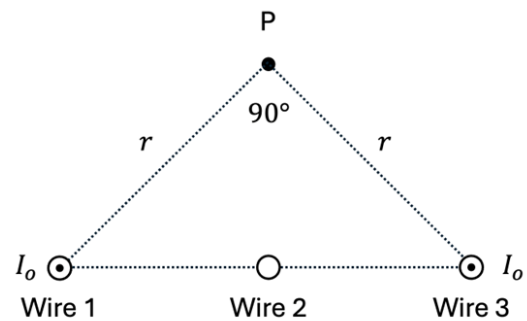
- A. All of them.
- B. None of them.
- C. Only ii.
- D. i. and ii.
- E. i. and iii.

- 8) (5 pts) Consider two different configurations of wires. In configuration A, a long thin wire carries current I_0 . At point X, a distance d away from the wire, the magnetic field is B_0 directed into the page. Configuration B is identical to configuration A, except a second wire carries current $2I_0$ in the opposite direction and point Y is a distance d away from each wire, as shown. What is the magnetic field at point Y in configuration 2?



- A. 0
 B. B_0 directed out of the page
 C. B_0 directed into the page
 D. $3B_0$ directed into the page
 E. None of the above.

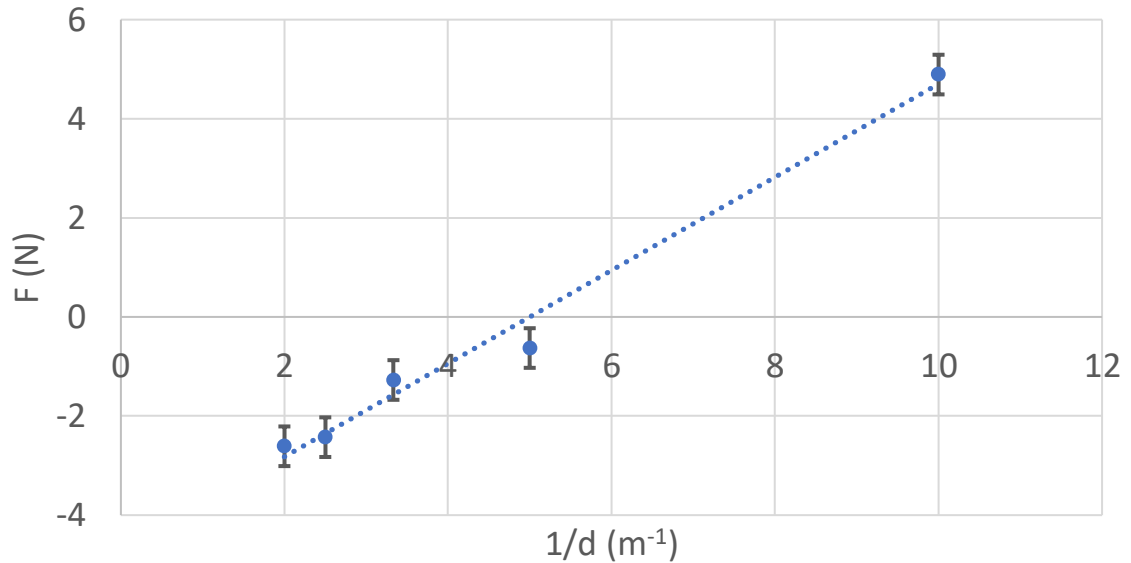
- 9) (5 pts) Three evenly spaced long thin wires carry currents perpendicular to the page, as shown. Wires 1 and 3 carry current I_0 out of the page. Wire 2 carries current of unknown value and direction. Is it possible for the magnetic field at point P to be zero?



- A. It is not possible.
 B. Yes, if wire 2 carries current I_0 into the page.
 C. Yes, if wire 2 carries current I_0 out of the page.
 D. Yes, if wire 2 carries current $2I_0$ into the page.
 E. Yes, if wire 2 carries current $2I_0$ out of the page.

II. Lab multiple choice (15 points)

10) (5 pts) In lab A3 a team placed two minty particles in the VR 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. Based on their measurements they produced the following graph of F as a function of $1/d$.



Which one of the following statements is consistent with the team's observation and the graph above?

- A. Positive force is repulsive.
- B. Negative force is repulsive.
- C. The team never measured any repulsive force.
- D. Not enough information is provided.

11) (5 pts) In Lab A4 a team explored a VR simulation that had two different types of exotic particles (not particles with electrical charge). The different types of particles could not be distinguished by their appearance. They spawned two particles and observed that they repelled. What can they conclude?

- A. They must be the same particle type.
- B. They must be different particle types.
- C. They do not have enough information to conclude if they are the same or different particle types.

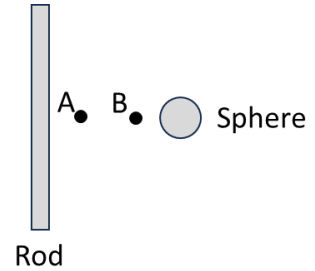
12) (5 pts) Consider the following relationship: $z = xy$. If $x = (10.0 \pm 0.3)$ N, and $y = (20.0 \pm 2.0)$ m, which of the following is consistent with how you should report the value of z according to the rules we use in PHYS 122?

- A. 200 ± 8 N·m
- B. 200 ± 20 N·m
- C. 200.0 ± 20.0 N·m
- D. 200 ± 26 N·m
- E. 200.0 ± 26.0 N·m

III. Lecture free response (25 points)

Use the following scenario for the next three questions.

A charged rod and a charged sphere are fixed in place near each other. The electrical potential is positive on the surface of the rod and negative on the surface of the sphere. The electric potential at infinity is zero. The following questions focus on positions A and B.



- 13) Consider a charged particle (not shown) moving to the right with an initial speed v_0 at point A such that it turns around when it reaches point B. The particle has mass m_p and an absolute value of charge q_p .

A. (5 pts) Is the particle positively or negatively charged? Explain your reasoning.

The particle is negatively charged. As the particle moves from point A to B it slows down so the kinetic energy decreases, and because the total energy is constant (there is no external work), that means that the electric potential energy, U , increases. The potential at the rod is greater than the potential at the sphere, so as the particle moves from A to B, the electric potential, V , decreases. Since $U = qV$, if U increases and V decreases, that means q must be negative.

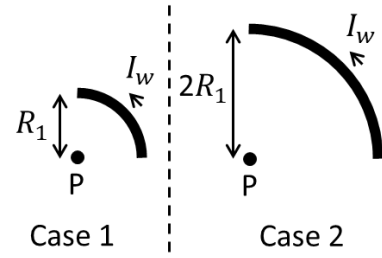
B. (7 pts) Write an expression for the electric potential difference between points A and B, $\Delta V_{BA} = V_B - V_A$, in terms of variables given (m_p , v_0 , and q_p). Show your work being sure to mention which equations you are using.

Considering rod-sphere-particle system the total energy is constant as there is no external work, so $K_A + U_A = K_B + U_B$
 The kinetic energy is given by $K = \frac{1}{2}mv^2$, and at B $K = 0$ since it is momentarily at rest.
 The potential energy is given by $U = qV$. From above we determined that q is negative, so $U = -q_pV$.
 Therefore $\frac{1}{2}m_p v_0^2 = -q_p(V_B - V_A)$, so $\Delta V_{BA} = \frac{m_p v_0^2}{2q_p}$

- 14) (6 pts) Consider the initial configuration shown above, if the charged sphere were removed would the electric potential at point A *increase, decrease or remain the same*? Explain your reasoning.

Increase. If the electric potential is zero at infinity, the potential due to a point charge is given by $V = \frac{kQ}{r}$, so for the surface of the rod to be at positive potential, there must be positive charge on the rod, and likewise for the surface of the sphere to have negative potential, there must be negative charge on the sphere. The total potential at point A is due to the sum of the potential caused by the rod and sphere. Since the sphere has negative charge it creates negative potential at all points, and therefore removing this potential, increases the potential at point A.

Consider two separate cases with a wire formed into a quarter circle with a current I_w flowing through it, and point P at the center of the circle, as shown. In case 1 the radius of the quarter circle is R_1 and in case 2 the radius is $2R_1$.



- 15) (7 pts) If the magnetic fields at point P in cases 1 and 2, respectively, are B_1 and B_2 , what is the ratio B_2/B_1 ? You should be able to enter a numerical answer but be sure to show your work and to mention which equations you use.

The magnetic field at the center of a coil is given by $B = \frac{\mu_0 NI}{2R}$. We have a quarter circle, and because of symmetry the magnetic field should be $\frac{1}{4}$ of that from a full circle with one loop ($N = 1$), so $B = \frac{\mu_0 I}{8R}$. The current is the same in both cases, so the only difference is the

radius of the loop, R . Therefore $\frac{B_2}{B_1} = \frac{\frac{\mu_0 I}{8R_2}}{\frac{\mu_0 I}{8R_1}} = \frac{R_1}{R_2} = \frac{R_1}{2R_1} = \frac{1}{2}$

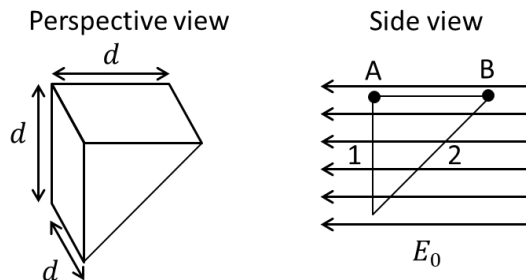
Alternatively:

The magnetic field from a current segment is given by $\vec{B} = \frac{\mu_0 I \Delta \vec{s} \times \hat{r}}{4\pi r^2}$. At each point on the wire $\Delta \vec{s}$ is perpendicular to \hat{r} , so $\Delta \vec{s} \times \hat{r} = \Delta s$, and the direction is always out of the page. Therefore, the magnitude of the magnetic field can be calculated by summing the magnetic field due to all the segments along the arc. The total arc length is given by $\Delta s = \frac{2\pi r}{4}$.

Therefore the total magnetic field is given by $B = \frac{\mu_0 I \pi r}{8\pi r^2} = \frac{\mu_0 I}{8r}$ (This is the same as the alternative, so from here the reasoning is the same).

IV. Tutorial free response (15 points)

Consider a triangular prism shaped Gaussian surface with side lengths shown in the perspective view. The Gaussian surface is in a uniform horizontal electric field with magnitude E_0 , as shown in the side view. Surface 1 is the vertical square on the left of the triangular prism, and surface 2 is the sloped rectangle on the right of the triangular prism.



16) (5 pts) Is the absolute value of the flux through surface 1 *greater than, less than, or equal to* the absolute value of the flux through surface 2? Explain your reasoning.

Equal. We can calculate the magnetic flux from the number of field lines passing through a surface. In this case the number entering through surface 2 is equal to the number exiting through surface 1.

Alternatively: No field lines terminate in the Gaussian surface, so there is no charge within the volume. Therefore, the flux entering surface 2, must be equal to the flux leaving surface 1.

Alternatively: The flux through a flat area in a uniform field is given by $\Phi_e = EA \cos \theta$. The electric field is equal at both surfaces. For surface 1 $\theta = 0$, so $\Phi_e = EA$, for surface 2 the area is given by $A_2 = A_1 / \cos \theta$

17) (5 pts) With the original electric field still in place, now a particle with positive charge is placed to the left of surface 1. Does the flux through surface 1 *increase, decrease, or remain the same*? Explain your reasoning.

Decrease. In the original configuration the electric flux through surface 1 is positive because the electric field points to the left and the area vector also points to the left. If a positive charge were placed to the left of surface 1, the electric field from the point charge would have components at all points on surface 1 that point to the right, so in the opposite direction from the area vector, so it would contribute negative flux to the surface. Therefore the total flux through surface 1 would decrease.

18) (5 pts) Now the particle is moved at constant speed a distance $d = 0.50$ m from points A to B. If the particle has charge $q_0 = 3.0 \times 10^{-9}$ C, and $E_0 = 5.0$ N/C, what is the change in potential energy, including the sign, of the particle-field system as the particle is moved from A to B? Show your work being sure to mention which equations you use.

The change in energy is given by $W_{ext} = \Delta K + \Delta U$. The particle is moved at constant speed so the kinetic energy does not change, $\Delta K = 0$. There is an electric force on the particle to the right, so the external force necessary to move it at constant speed must be to the right with equal magnitude, so $q_0 E_0$. The work is the force multiplied by the distance, so therefore $\Delta U = q_0 E_0 d = (3.0 \times 10^{-9} \text{ C})(5.0 \text{ N/C})(0.50 \text{ m}) = (7.5 \times 10^{-9} \text{ J})$