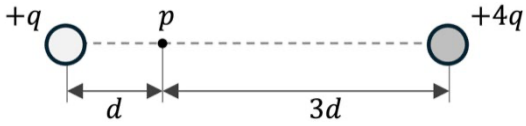
I. Lecture Multiple Choice (45 pts)

1. [5 pts] Two particles with charge $+q$ and $+4q$ are separated by a distance $4d$. If the electric potential is defined to be zero at points infinitely far from these particles, what is the electric potential at point p?



A) $\frac{1}{4\pi\varepsilon_o}\frac{7q}{3d}$

B) $\frac{1}{4\pi\varepsilon_o}\frac{4q}{3d}$

C) $\frac{1}{4\pi\varepsilon_o}\frac{13q}{9d}$

D) 0

E) None of the above

2. [5 pts] The electric potential in a region of space is described by $V(x)$, where V is measured in volts, and x is measured in meters, and the constant values are in the appropriate units such that each term is in Volts:

$$V(x) = (3 - 12x - x^2)\text{Volts}$$

Which one of the following statements is TRUE?

A) There is a constant net electric field in this region.

B) The electric field points in the negative direction at the origin.

C) A positively charged particle at $x = +2$ m will accelerate in the negative direction.

D) Between $x = 0$ m and $x = +2$ m the change in the electric potential is positive.

E) At $x = +2$ m the electric field points in the positive direction.

3. [5 pts] A negatively charged particle moving in the positive-x direction speeds up due to the influence of a constant electric field, E_0, along the x-direction. Which one of the following sets are possible values of the quantities associated with this particle's motion: the electric field E_0, along the x-direction, the potential at the initial position V_0, and the change in potential between the initial and final positions, ΔV?

   A) $\overrightarrow{E_0} = -(10\ \mathrm{N/C})\hat{\imath}$ $\quad V_0 = -5\ \mathrm{V}$ $\quad \Delta V = -2\ \mathrm{V}$

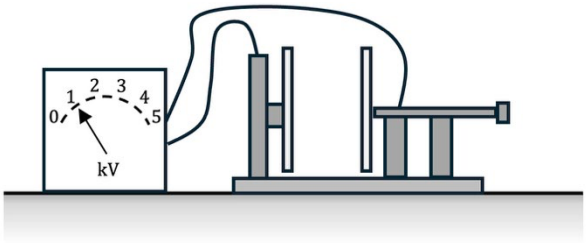
   B) $\overrightarrow{E_0} = +(10\ \mathrm{N/C})\hat{\imath}$ $\quad V_0 = -5\ \mathrm{V}$ $\quad \Delta V = +2\ \mathrm{V}$

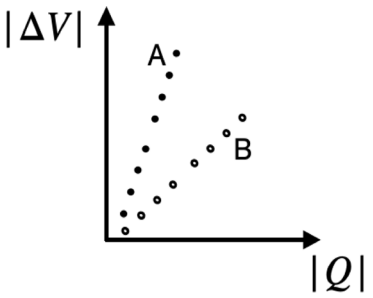
   C) $\overrightarrow{E_0} = -(10\ \mathrm{N/C})\hat{\imath}$ $\quad V_0 = +5\ \mathrm{V}$ $\quad \Delta V = -2\ \mathrm{V}$

   D) $\overrightarrow{E_0} = +(10\ \mathrm{N/C})\hat{\imath}$ $\quad V_0 = +5\ \mathrm{V}$ $\quad \Delta V = +2\ \mathrm{V}$

   E) $\overrightarrow{E_0} = -(10\ \mathrm{N/C})\hat{\imath}$ $\quad V_0 = -5\ \mathrm{V}$ $\quad \Delta V = +2\ \mathrm{V}$

4. [5 pts] Using the adjustable-width capacitor demonstrated in lecture (illustrated at right), a plastic rod that is charged using a wool cloth is used to add charge to one of the capacitor plates. Charge is added eight times, and the potential difference across the plates is measured after each addition. This experiment is conducted twice, once with a dielectric filling the gap between the plates, and once with just air filling the gap. The data are plotted at right. Which data set, if either, could correspond to the trial in which a dielectric was used to fill the gap in the capacitor?





   A) Data set A

   B) Data set B

   C) There is not enough information, we would also need to know whether the added charge is positive or negative.

   D) There is not enough information, we would also need to know the value of the plate separation in each case.

5. [5 pts] A long, straight, cylindrical wire carries current uniformly distributed across its cross-section. The wire has length L_0 and a radius r_0 with an electric field E_0 between the ends of the wire. If you double both the length and the radius of the wire without changing E_0, which quantities will decrease? *(read all choices, then select one answer)*

   A) resistivity

   B) resistance

   C) current density

   D) At least two of the above quantities will decrease.

   E) Neither the resistivity, resistance nor the current density will decrease.

6. [5 pts] A wire has length L_0 and a radius r_0. An electric potential difference ΔV_0 between the ends causes a current I_0 to flow through the wire. If you replace the wire with one made from the same material and length, but has a radius of $r_{new} = 2r_0$, and reduce the electric potential difference to $\Delta V_{new} = \frac{1}{2}\Delta V_0$ what will be the resulting current, I_{new}?

   A) $I_{new} = I_0$

   B) $I_{new} = 4I_0$

   C) $I_{new} = 2I_0$

   D) $I_{new} = \frac{1}{2}I_0$

   E) $I_{new} = \frac{1}{4}I_0$

7. [5 pts] A long, straight, cylindrical wire carries current uniformly distributed across its cross-section. The magnitude of the magnetic field at the point P, a distance $R/2$ from the center of the wire, is three times that at point Q, outside of the wire ($|\vec{B}_P| = 3|\vec{B}_Q|$). How far is the point Q from the axis of the wire in terms of R?

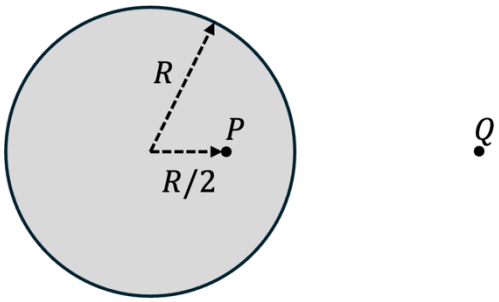


Diagram not drawn to scale.

A) $\frac{3}{2}R$

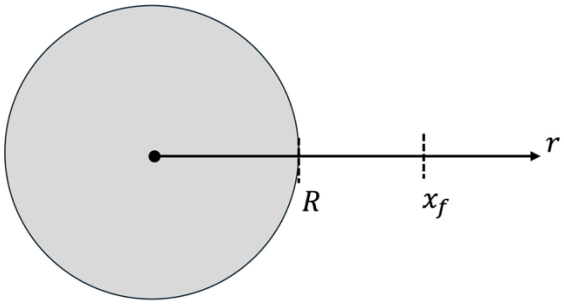
B) $2R$

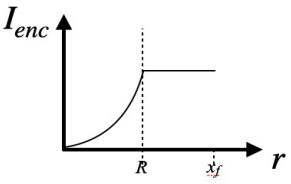
C) $3R$

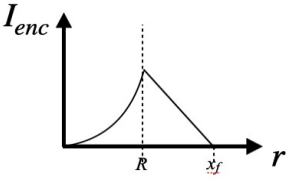
D) $6R$

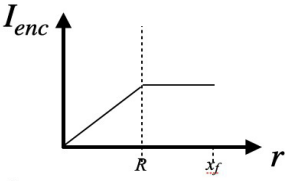
E) None of these answers are correct.

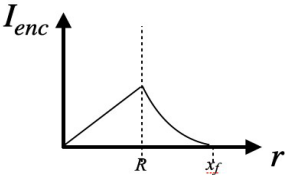
8. [5 pts] The figure shows a cross section of a long, straight, cylindrical wire that carries current uniformly distributed across its cross-section. The wire has a radius R and has a current I_0 through it. Which one of the following graphs best describes the current enclosed by a circular closed curve of radius r centered at the origin shown, for values of r ranging from 0 to x_f?



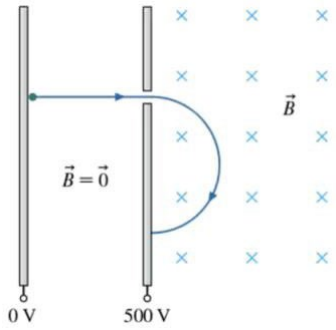
A.


B.


C.


D.


9. [5 pts] An electron that is accelerated from rest through a potential of 500 V is injected into a uniform 9.0×10^{-3} T magnetic field. Once in the magnetic field, the electron completes half a revolution. Which one of the following values is closest to the radius of its path in the magnetic field?



A) 17 mm

B) 6.2 mm

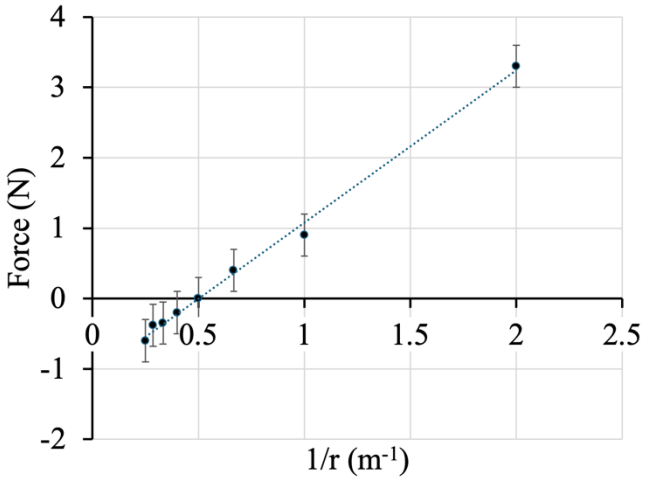
C) 12 mm

D) 21 mm

E) 8.4 mm

II. Lab Multiple Choice (15 pts)

10. [5 pts] In Lab A3, students measured the force, F, on a minty particle, while varying the distance, r, from another minty particle. The students defined a positive reading on their force meter as a repulsive force and a negative reading as an attractive force. After they had gathered their data, they formed the plot shown at right. Which statement below is consistent with the data in the graph?



A) The students use the separation distance as their independent variable and vary the distance in steps of 0.5 m.

B) The students use the separation distance as their dependent variable and vary the distance in steps of 0.25 m.

C) The minty particles exert a force on one another that is approximately zero when the particles are separated by 0.5 m.

D) When the separation distance is 0.4 m, the force between the particles is attractive.

E) None of the above statements are consistent with the graph.

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-thousandth of a newton. Their measurements are shown at right. How should the students report the average force?

Trial	Force (N)
1	0.525
2	0.525
3	0.530

A) (0.53 ± 0.005) N

B) (0.53 ± 0.05) N

C) (0.527 ± 0.003) N

D) (0.527 ± 0.005) N

E) (0.53 ± 0.003) N

12. [5 pts] In Lab A4, a group creates three particles and paints them with different colors: blue, green, and red. The group members observe the following interactions between two particles when you place each pair under identical conditions. Assume that they can duplicate the green particle and observe the interaction between two identical green particles for the first interaction (Green – Green).

- Green-Green: repel
- Green-Blue: no interaction
- Green-Red: attract
- Blue-Red: attract

Use the information above to determine (1) whether the green and red particles are of the same type or are of different types, and (2) whether the green and blue particles are of the same type or are of different types.

Which of the choices (A to D) in the table below describes the nature of the particles?

Particles	Choice A	Choice B	Choice C	Choice D
Green and Red	Different types	Same type	Same type	Different types
Green and Blue	Different types	Different types	Same type	Same type

III. Lecture Free Response (25 pts)

Initially, the plates of a capacitor are a distance d_o apart, and the electric potential difference between the plates is ΔV_o. The charge on one plate is $+Q_o$, the charge on the other plate is $-Q_o$, and the magnitude of the electric field between the plates is E_o.

The setup is then modified: the plate separation is increased to $3d_o$ and the potential difference between the plates is increased to $6\Delta V_o$.

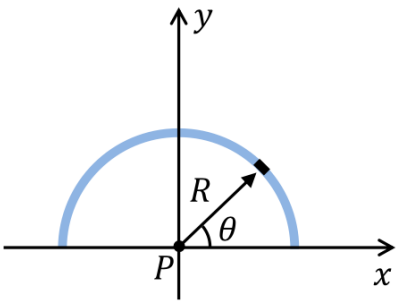
13. [5 pts] If the original capacitance is C_o, what is C_f, the capacitance after the setup is modified? Answer in terms of C_o. Explain your reasoning.

14. [5 pts] What is E_f, magnitude of the electric field between the plates after the setup is modified? Answer in terms of E_o. Explain your reasoning.

15. [5pts] What is Q_f, the charge on the positive plate after the setup is modified? Answer in terms of Q_o. Explain your reasoning.

16. [5 pts] If the original energy density stored in the electric field between the plates is u_o, what is u_f, the energy density after the setup is modified? Answer in terms of u_o. Explain your reasoning.

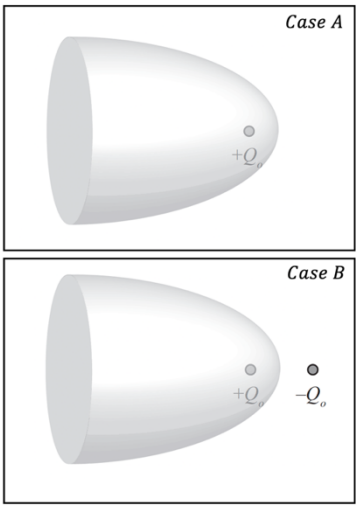
17. [5 pts] A thin semi-circular rod of radius R has a charge Q uniformly distributed along it. The center of the arc, point P, is located at the origin as shown. Set up an integral that integrates with respect to θ (angle from the x-axis) to calculate the electric potential at P. Assume that potential is zero infinitely away from the rod. Express the integrand in terms of Q, R, θ, and k (the electric force constant) and include appropriate limits. You do not need to evaluate the integral.



$$\int_{(\quad)}^{(\quad)} (\qquad\qquad\qquad\qquad) \, d\theta$$

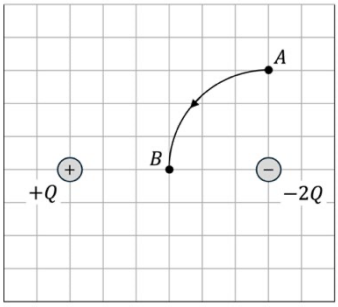
IV. Tutorial Free Response (15 pts)

In case A, a closed Gaussian surface encloses a point charge $+Q_0$ as shown. In case B, a second point charge $-Q_0$ is placed to the right of the Gaussian surface as shown.



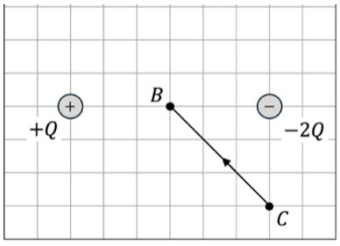
18. [5 pts] Is the value of the flux through the entire Gaussian surface in case A *greater than, less than,* or *equal to* the value of the flux through the entire Gaussian in case B? Explain.

19. [5 pts] Two point charges, $+Q$ and $-2Q$ are fixed in place as shown. Suppose a hand moves a positive test charge, $+q_0$, at constant speed from point A to point B along the arc shown.



Is the work done on the positive test charge by the hand *positive, negative,* or *zero*? Explain.

20. [5 pts] In a separate experiment, a hand moves a negative test charge, $-3q_0$, at constant speed from point C to point B along the straight-line path shown at right.



Is the potential difference that the $-3q_0$ travels through from point C to point B *greater than, less than,* or *equal to* the potential difference that the $+q_0$, traveled through from point A to point B in question 19? Explain.