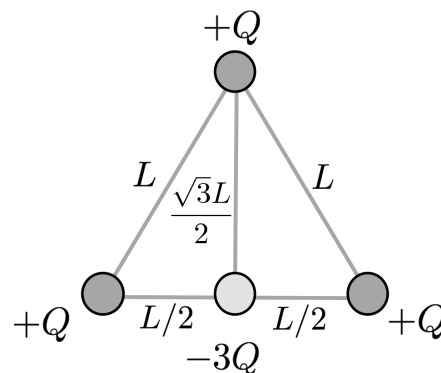


A

- Print your name, quiz form number (3 digits at the top of this form), and student number (9 digit Georgia Tech ID number) in the section of the answer card labeled "Student Identification."
- Bubble the Quiz Form Number in columns 1–3, skip column 4, then bubble your Student Number in columns 5–13.
- Free-response questions are numbered I–III. For each, make no marks and leave no space on your card. Show all your work clearly, including all steps and logic. Box your answer.
- Multiple-choice questions are numbered 1–10. For each, select the answer most nearly correct, circle this answer on your quiz, and bubble it on your answer card. Do not put any extra marks on the card.
- Turn in your quiz and answer card as you leave. Your score will be posted when your quiz has been graded. Quiz grades become final when the next quiz is given.
- You may use a calculator that cannot store letters, but no other aids or electronic devices.

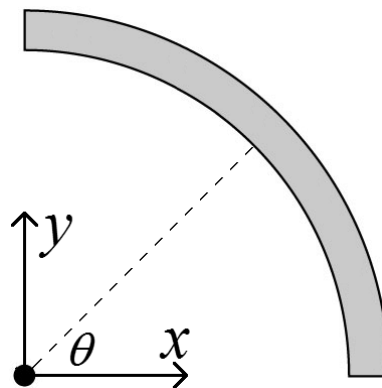
- I. (17 points) Three point charges, each carrying a charge $Q = +6.0 \text{ nC}$, are placed on an equilateral triangle of side length $L = 3.0 \text{ mm}$. An additional point charge, carrying a charge $-3Q$, is placed on one side of the triangle as drawn below. Calculate the electric potential energy of this system, relative to zero when the four charges are infinitely far away from each other.



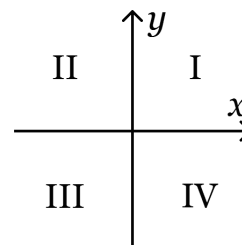
- II. (16 points) A thin non-uniform charged rod of length L is bent into a quarter-circle. When placed as shown, it has a linear charge density λ that varies with angle θ according to

$$\lambda = \lambda_0 \sin \theta$$

where λ_0 is a positive constant and θ is measured as usual, from the $+x$ axis toward the $+y$ axis. What is the magnitude of the resulting electric potential at the center of the arc (the origin), with respect to zero at infinite distance?



1. (5 points) In the problem above, in what quadrant, if any, is the direction of the potential at the center of the arc (the origin)?
- (a) The potential is directed in quadrant *II*.
 - (b) The potential is directed in quadrant *III*.
 - (c) The potential is directed in quadrant *IV*.
 - (d) The potential is directed in quadrant *I*.
 - (e) The potential has no direction.

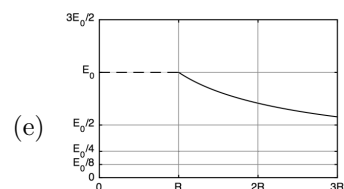
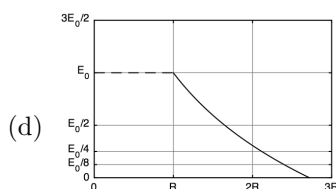
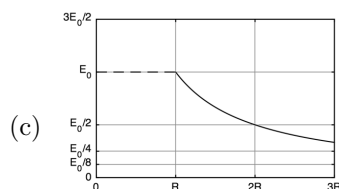
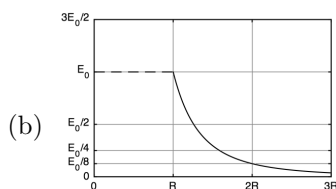
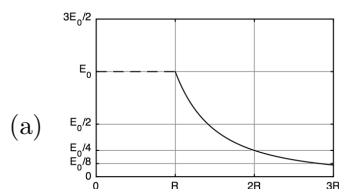


- III. (17 points) Calculate the magnitude of the electric field *inside* a solid, non-uniformly charged sphere of radius R . The charge density inside the sphere is

$$\rho(r) = \rho_0 \frac{r^2}{R^2}$$

for $r < R$, where ρ_0 is a constant and r is the distance from the center of the sphere.

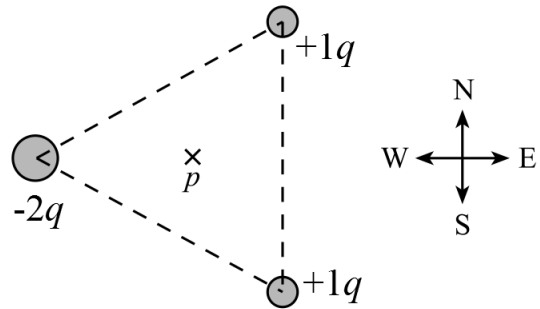
2. (5 points) Which sketch shows the electric field *outside* the sphere of the previous question? (The electric field inside the sphere is *not* shown accurately. It is rendered as a straight dashed line).



3. (5 points) Two positive charges $+q$ and a negative charge $-2q$ are placed at the vertices of an equilateral triangle, as shown. Use the convention that $V = 0$ at infinity.

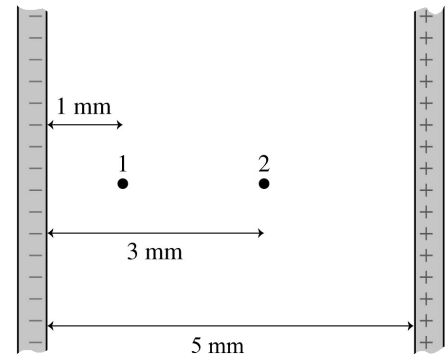
Which statement about the point p , at the center of the triangle, is true?

- (a) $V = 0$; $\vec{E}$ points East.
- (b) $V < 0$; $\vec{E}$ points West.
- (c) V is undefined; the direction of $\vec{E}$ is also undefined because $\vec{E}$ has zero magnitude.
- (d) $V = 0$; the direction of $\vec{E}$ is undefined because $\vec{E}$ has zero magnitude.
- (e) $V = 0$; $\vec{E}$ points West.



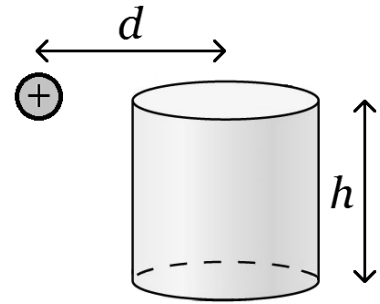
4. (5 points) The plates in an ideal parallel plate capacitor are 5.0 mm apart, as shown. The potential difference between these plates is 15 V. Point 1 is 1.0 mm from the negative plate, and point 2 is 3.0 mm from the negative plate. If it can be determined, what is the potential difference **from** point 1 **to** point 2?

- (a) $+6.0 \text{ V}$
- (b) Cannot be determined until the zero point for potential is specified.
- (c) -6.0 V
- (d) -2.4 V
- (e) $+2.4 \text{ V}$



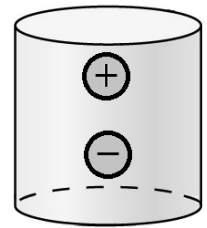
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5. (5 points) A positively charged particle lies in the plane of a cylindrical surface's top, a distance d from the axis, as shown. The cylinder has height h . What is the sign, if any, of the flux through the cylinder's curved side?

- (a) Φ_{side} is negative if $d < h$, but Φ_{side} is positive if $d > h$.
(b) Φ_{side} is negative.
(c) Φ_{side} is positive if $d < h$, but Φ_{side} is negative if $d > h$.
(d) Φ_{side} is positive.
(e) Φ_{side} is zero (no sign).



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6. (5 points) A positively charged particle and a negatively charged particle, each having charge magnitude q , lie on the axis of a cylindrical surface, equidistant from the ends, as shown. Rank the flux through the top, side, and bottom of the cylinder, from greatest to least. Remember that electric flux can be positive or negative.

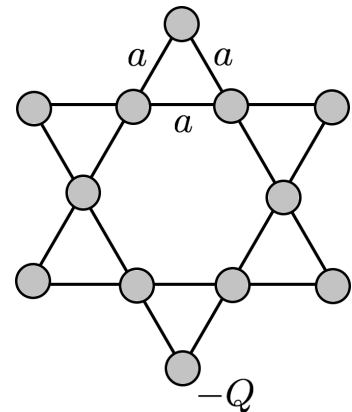
- (a) $\Phi_{\text{bottom}} > \Phi_{\text{side}} > \Phi_{\text{top}}$
(b) $\Phi_{\text{top}} = \Phi_{\text{bottom}} > \Phi_{\text{side}}$
(c) $\Phi_{\text{top}} = \Phi_{\text{side}} = \Phi_{\text{bottom}}$
(d) $\Phi_{\text{side}} > \Phi_{\text{top}} > \Phi_{\text{bottom}}$
(e) $\Phi_{\text{top}} > \Phi_{\text{side}} > \Phi_{\text{bottom}}$



-
7. (5 points) A proton is sent with a velocity $v_0 = 3.0 \times 10^6 \text{ m/s}$ (1% of the speed of light) toward a mercury nucleus containing $Z = 80$ protons, initially located infinitely far away. The radius of a mercury nucleus is so small ($10 \text{ fm} = 10^{-14} \text{ m}$), that the nucleus can be described as a point charge. How close to the nucleus will the proton get? Reminder: 1 pico-meter (pm) = 10^{-12} m .

- (a) 1.97 pm
- (b) 1.43 pm
- (c) 0.81 pm
- (d) 6.61 pm
- (e) 2.45 pm

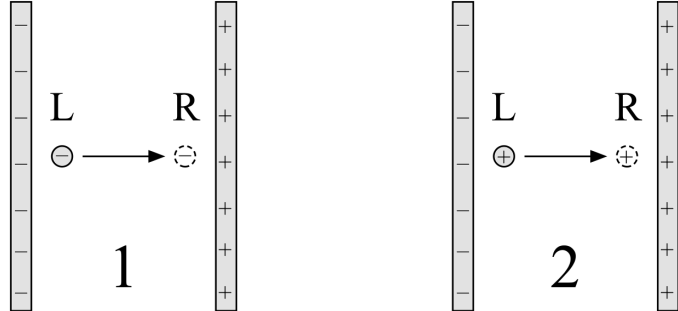
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8. (5 points) Twelve identical point charges, each carrying a charge $-Q$, are organized on the “kagome” pattern sketched below. Each triangle in the pattern is equilateral with a side length a . The electric potential energy of the system is U_0 . What is the electric potential energy U_1 of the system when the distance a is multiplied by 3? (“Kagome” is the Japanese word for traditional bamboo baskets having this geometry.)



- (a) $U_1 = U_0/\sqrt{3}$
- (b) $U_1 = U_0/\sqrt{2}$
- (c) $U_1 = U_0/3$
- (d) $U_1 = U_0/6$
- (e) $U_1 = U_0/9$

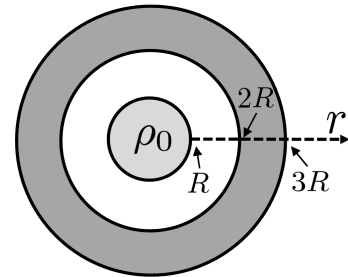
9. (5 points) Consider two scenarios inside identical capacitors. In each scenario, the capacitor is charged identically, with charge $-Q$ on the left-hand plate and $+Q$ on the right-hand plate. In scenario 1, a negatively charged particle is moved from the left (L) to the right (R). In scenario 2, a positively charged particle (of equal magnitude) is moved from L to R. In each case, the potential difference is defined as $\Delta V = V_R - V_L$, and the potential energy difference is defined as $\Delta U = U_R - U_L$. Which of the statements below is true?

- (a) $\Delta V_1 > 0$; $\Delta U_1 > 0$; $\Delta V_2 < 0$; $\Delta U_2 > 0$
 (b) $\Delta V_1 > 0$; $\Delta U_1 > 0$; $\Delta V_2 > 0$; $\Delta U_2 < 0$
 (c) $\Delta V_1 > 0$; $\Delta U_1 < 0$; $\Delta V_2 > 0$; $\Delta U_2 > 0$
 (d) $\Delta V_1 > 0$; $\Delta U_1 > 0$; $\Delta V_2 < 0$; $\Delta U_2 < 0$
 (e) $\Delta V_1 < 0$; $\Delta U_1 < 0$; $\Delta V_2 < 0$; $\Delta U_2 > 0$



10. (5 points) An insulating spherical bead of radius R is charged with a uniform positive volume charge density ρ_0 . The bead is placed in the center of a hollow conducting sphere of inner radius $2R$ and outer radius $3R$. The hollow conducting sphere is initially neutral. What is surface charge density η on the exterior surface of the hollow sphere?

- (a) $\eta = +\rho_0 R/12$
 (b) $\eta = -\rho_0 R/12$
 (c) $\eta = 0$
 (d) $\eta = -\rho_0 R/27$
 (e) $\eta = +\rho_0 R/27$



$$k = \frac{1}{4\pi\epsilon_0}$$

$$\Delta V = - \int \vec{E} \cdot d\vec{s}$$

$$V = k \frac{q}{r}$$

$$\Delta U = q \Delta V$$

$$I = dq/dt$$

$$P = I \Delta V$$

$$R = \frac{\Delta V}{I}$$

Series :

$$\frac{1}{C_{\text{eq}}} = \sum \frac{1}{C_i}$$

$$R_{\text{eq}} = \sum R_i$$

Parallel :

$$\frac{1}{R_{\text{eq}}} = \sum \frac{1}{R_i}$$

$$C_{\text{eq}} = \sum C_i$$

$$\vec{E} = k \frac{q}{r^2} \hat{r}$$

$$\vec{F} = k \frac{q_1 q_2}{r^2} \hat{r}$$

$$\vec{F} = q \vec{E}$$

$$\vec{p} = q \vec{d}$$

$$\vec{\tau} = \vec{p} \times \vec{E}$$

$$U = -\vec{p} \cdot \vec{E}$$

$$|\vec{E}| \propto \frac{|\vec{p}|}{r^3}$$

$$\Phi_E = \int \vec{E} \cdot d\vec{A}$$

$$\epsilon_0 \oint \vec{E} \cdot d\vec{A} = q_{\text{enclosed}}$$

$$\oint \vec{E} \cdot d\vec{\ell} = -\frac{d\Phi_E}{dt}$$

$$C = \frac{Q}{\Delta V}$$

$$C = \epsilon_0 \frac{A}{d}$$

$$U = \frac{1}{2} C [\Delta V]^2$$

$$R = \rho \frac{\ell}{A}$$

$$\tau_C = RC$$

$$u_E = \frac{1}{2} \epsilon_0 E^2$$

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

$$d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{d\vec{\ell} \times \hat{r}}{r^2}$$

$$\vec{F} = q \vec{v} \times \vec{B}$$

$$\vec{F} = I \vec{\ell} \times \vec{B}$$

$$\vec{\mu} = NI \vec{A}$$

$$\vec{\tau} = \vec{\mu} \times \vec{B}$$

$$U = -\vec{\mu} \cdot \vec{B}$$

$$\Phi_B = \int \vec{B} \cdot d\vec{A}$$

$$\oint \vec{B} \cdot d\vec{A} = 0$$

$$\oint \vec{B} \cdot d\vec{\ell} = \mu_0 (I_c + I_d)$$

$$L = \frac{\Phi_B}{I}$$

$$L = \mu_0 N^2 \frac{A}{\ell}$$

$$U = \frac{1}{2} LI^2$$

$$B = \mu_0 n I$$

$$\tau_L = L/R$$

$$u_B = \frac{1}{2} B^2$$

$$q = q_{\text{max}} \left(1 - e^{-t/\tau_c} \right)$$

$$q = q_0 e^{-t/\tau_c}$$

$$I = I_{\text{max}} \left(1 - e^{-t/\tau_L} \right)$$

$$I = I_0 e^{-t/\tau_L}$$

$$I = \int \vec{J} \cdot d\vec{A}$$

$$\vec{J} = \sigma \vec{E}$$

$$\mathcal{E} = -N \frac{d\Phi_B}{dt}$$

$$I_d = \epsilon_0 \frac{d\Phi_E}{dt}$$

$$\mathcal{E} = -L \frac{dI}{dt}$$

$$c = f\lambda = \frac{|\vec{E}|}{|\vec{B}|}$$

$$\vec{S} = \frac{1}{\mu_0} \vec{E} \times \vec{B}$$

Fundamental Charge $e = 1.602 \times 10^{-19} \text{ C}$

Earth's gravitational field $g = 9.81 \text{ N/kg}$

Coulomb constant $K = 8.988 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$

Mass of an Electron $m_e = 9.109 \times 10^{-31} \text{ kg}$

Mass of a Proton $m_p = 1.673 \times 10^{-27} \text{ kg}$

Vacuum Permittivity $\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2$

Unless otherwise directed, friction, drag, and gravity should be neglected, and all batteries and wires are ideal.

All derivatives and integrals in free-response problems must be evaluated.

