- *Print* your name and 9 digit Georgia Tech ID number *clearly* in the spaces below.
- You may use a calculator that cannot store letters, but no other aids or electronic devices.
- Free-response questions are numbered I–III. Show all your work clearly, including all steps and logic. Box your answer.
- Multiple-choice questions are numbered 1–7. For each, select the answer most nearly correct, circle this answer on your quiz, and bubble it on your answer sheet.
- Your score will be posted when your quiz has been graded. Quiz grades become final when the next is given.

- Be sure your writing is *dark*. Blue or black ink is recommended.
- Do not make any erasures in your free-response work. Cross out anything you do not want evaluated.
- Nothing written in the top margins will be evaluated.
- The standard formula sheet is on the back of this page. You may remove it from the quiz form if you wish, but it must be submitted.
- The answer sheet for multiple-choice questions is the last page of the quiz form. You may remove it from the quiz form if you wish, but don't forget to submit it.
- If the page for a free-response problem has insufficient space for your work, you may use the back of the answer sheet. Make a note on the problem page, so graders know where to find your work. This is the only extra sheet of work that can be evaluated.

Pages 9 and 10 had no questions

Quiz and Exam Formulæ & Constants

$$K = \frac{1}{4\pi\epsilon_0}$$
$$\Delta V = -\int \vec{E}\cdot d\vec{s}$$
$$V = K\frac{q}{r}$$
$$\Delta U = q\,\Delta V$$
$$I = dq/dt$$
$$P = I\,\Delta V$$
$$R = \frac{\Delta V}{I}$$

Series :
$$\frac{1}{C_{\text{eq}}} = \sum \frac{1}{C_i}$$
$$R_{\text{eq}} = \sum R_i$$

Parallel :
$$\frac{1}{R_{\text{eq}}} = \sum \frac{1}{R_i}$$
$$C_{\text{eq}} = \sum C_i$$

$$\vec{E} = K\frac{q}{r^2}\hat{r}$$
$$\vec{F} = K\frac{q_1 q_2}{r^2}\hat{r}$$
$$\vec{F} = q\vec{E}$$
$$\vec{p} = q\vec{d}$$
$$\vec{\tau} = \vec{p}\times\vec{E}$$
$$U = -\vec{p}\cdot\vec{E}$$
$$|\vec{E}| \propto \frac{|\vec{p}|}{r^3}$$
$$\Phi_{\text{E}} = \int \vec{E}\cdot d\vec{A}$$
$$\epsilon_0 \oint \vec{E}\cdot d\vec{A} = q_{\text{enclosed}}$$
$$\oint \vec{E}\cdot d\vec{\ell} = -\frac{d\Phi_{\text{B}}}{dt}$$
$$C = \frac{Q}{\Delta V}$$
$$C = \epsilon_0 \frac{A}{d}$$
$$U = \tfrac{1}{2} C\,[\Delta V]^2$$
$$R = \rho\frac{\ell}{A}$$
$$\tau_{\text{C}} = RC$$
$$u_{\text{E}} = \tfrac{1}{2}\epsilon_0 E^2$$

$$\vec{B} = \frac{\mu_0 q}{4\pi}\frac{\vec{v}\times\hat{r}}{r^2}$$
$$d\vec{B} = \frac{\mu_0 I}{4\pi}\frac{d\vec{\ell}\times\hat{r}}{r^2}$$
$$\vec{F} = q\vec{v}\times\vec{B}$$
$$\vec{F} = I\vec{\ell}\times\vec{B}$$
$$\vec{\mu} = NI\vec{A}$$
$$\vec{\tau} = \vec{\mu}\times\vec{B}$$
$$U = -\vec{\mu}\cdot\vec{B}$$
$$\Phi_{\text{B}} = \int \vec{B}\cdot d\vec{A}$$
$$\oint \vec{B}\cdot d\vec{A} = 0$$
$$\oint \vec{B}\cdot d\vec{\ell} = \mu_0 (I_{\text{c}} + I_{\text{d}})$$
$$L = \frac{\Phi_{\text{B}}}{I}$$
$$L = \mu_0 N^2 \frac{A}{\ell}$$
$$U = \tfrac{1}{2} L I^2$$
$$B = \mu_0 n I$$
$$\tau_{\text{L}} = L/R$$
$$u_{\text{B}} = \frac{1}{2\mu_0} B^2$$

$$q = q_{\max}\left(1 - e^{-t/\tau_{\text{C}}}\right)$$
$$q = q_0 e^{-t/\tau_{\text{C}}}$$
$$I = I_{\max}\left(1 - e^{-t/\tau_{\text{L}}}\right)$$
$$I = I_0 e^{-t/\tau_{\text{L}}}$$
$$I = \int \vec{J}\cdot d\vec{A}$$
$$\vec{J} = \sigma\vec{E}$$
$$\mathcal{E} = -N\frac{d\Phi_{\text{B}}}{dt}$$
$$I_d = \epsilon_0 \frac{d\Phi_{\text{E}}}{dt}$$
$$\mathcal{E} = -L\frac{dI}{dt}$$
$$c = f\lambda = \frac{|\vec{E}|}{|\vec{B}|}$$
$$\vec{S} = \frac{1}{\mu_0}\vec{E}\times\vec{B}$$

Fundamental Charge $e = 1.602\times 10^{-19}\,\text{C}$
Earth's gravitational field $g = 9.81\,\text{N/kg}$
Coulomb constant $K = 8.988\times 10^{9}\,\text{N·m}^2/\text{C}^2$
Speed of Light $c = 2.998\times 10^{8}\,\text{m/s}$

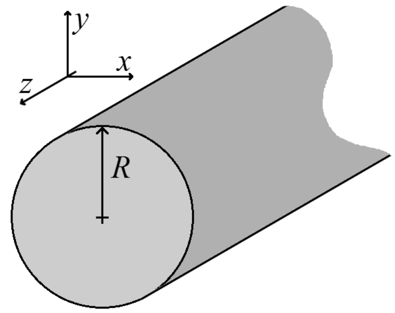
Mass of an Electron $m_{\text{e}} = 9.109\times 10^{-31}\,\text{kg}$
Mass of a Proton $m_{\text{p}} = 1.673\times 10^{-27}\,\text{kg}$
Vacuum Permittivity $\epsilon_0 = 8.854\times 10^{-12}\,\text{C}^2/\text{N·m}^2$
Vacuum Permeability $\mu_0 = 4\pi\times 10^{-7}\,\text{T·m/A}$

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. Problems about magnitudes will state so explicitly.

I. (16 points) A cylindrical wire with radius R carries a current density $\vec{J}$ that depends on distance r from the cylinder axis according to

$$\vec{J} = J_0 \frac{R}{r}\,\hat{k}$$

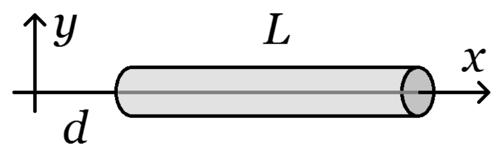
where $J_0 = 1.5 \times 10^5\,\mathrm{A/m^2}$. If the wire carries a total current of $6.0\,\mathrm{A}$, what is the radius of the wire?



II. (16 points) A thin rod with length L lines on the $+x$ axis, with one end at $x = d$ and the other at $d + L$, as shown. Its linear charge density λ depends of position x according to

$$\lambda = \lambda_0 \left(\frac{d}{x}\right)$$

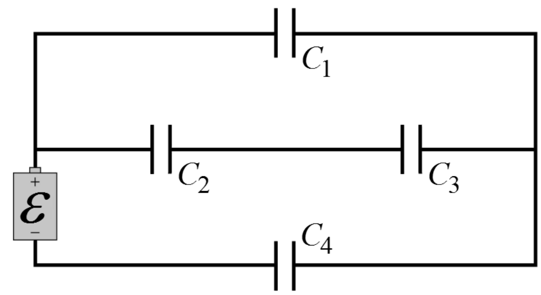
where λ_0 is a positive constant. What is the magnitude of the electric potential at the origin, with respect to zero at infinite distance? Express your answer in terms of parameters defined in the problem, and physical or mathematical constants.



1. (6 points) In the problem above, what is the direction, if any, of the electric potential at the origin?

   (a) In the $-x$ direction.
   (b) No direction, as the electric potential is zero.
   (c) In the $+x$ direction.
   (d) No direction, as this is not a meaningful question.

III. (16 points) Each of the four capacitors in the circuit shown has a identical capacitance C. The battery has a potential difference $\mathcal{E}$. What is the potential difference across capacitor C_1? Express your answer in terms of parameters defined in the problem, and physical or mathematical constants.



2. (6 points) In the problem above, let the charge on capacitor C_1 be Q_1. If a different battery were used in the circuit, with a potential difference twice that of the battery above (that is, $\mathcal{E}' = 2\mathcal{E}$), what would be the resulting charge Q_1' on capacitor C_1?

(a) $Q_1' = 2Q_1$
(b) $Q_1' = Q_1/2$
(c) $Q_1' = Q_1$
(d) $Q_1' = 4Q_1$
(e) $Q_1' = Q_1/4$

3. (8 points) A parallel-plate capacitor is connected to a battery with emf $\mathcal{E}$. While it remains connected, insulating handles are used to push the plates closer together. As the distance between the plates decreases, how is the charge magnitude on the plates affected? How is the electric field magnitude between the plates affected?

   (a) Charge magnitude decreases. Electric field magnitude increases.
   (b) Charge magnitude decreases. Electric field magnitude decreases.
   (c) Charge magnitude is unchanged. Electric field magnitude decreases.
   (d) Charge magnitude increases. Electric field magnitude increases.
   (e) Charge magnitude increases. Electric field magnitude is unchanged.

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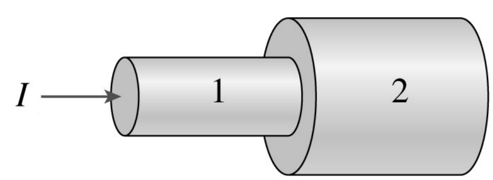
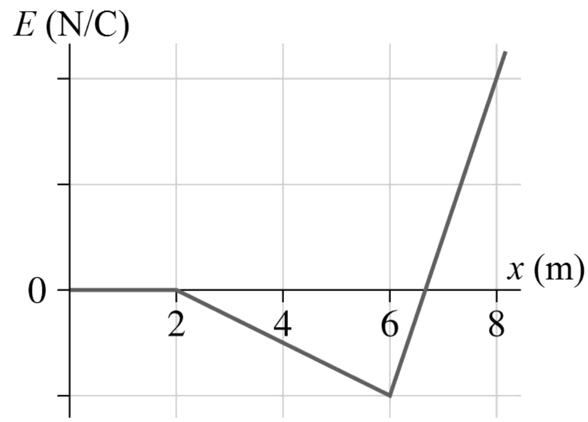
4. (8 points) The wire shown consists of two segments of different diameters made from different materials. The conductivity of segment 2 is half that of segment 1 (that is, $\sigma_2 = \sigma_1/2$). If segment 1 has radius R_1, what radius of segment 2 would result in each segment having the same electric field?

   (a) $R_2 = 2R_1$
   (b) $R_2 = R_1\sqrt{2}$
   (c) $R_2 = R_1$
   (d) $R_2 = 2R_1\sqrt{2}$
   (e) $R_2 = 4R_1$



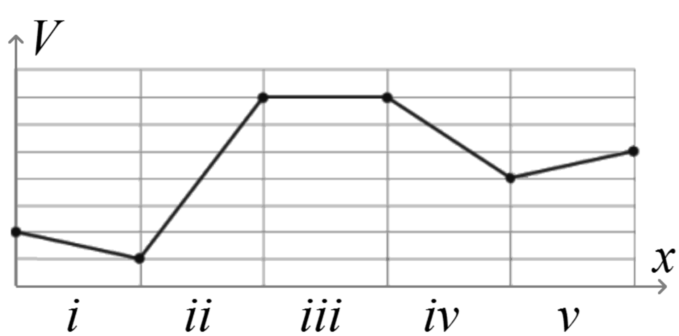
5. (8 points) The electric field in a region of space depends on position x, as shown. If the electric potential is zero at $x = 0$, at what location in the range $x = 0$ to $x = 8.0\,\mathrm{m}$ does the electric potential have its maximum value?

(a) At $x = 6.0\,\mathrm{m}$.
(b) At $x = 0.0\,\mathrm{m}$.
(c) At $x = 8.0\,\mathrm{m}$.
(d) At $x = 2.0\,\mathrm{m}$.
(e) At $x = 6.7\,\mathrm{m}$.



6. (8 points) Electric potential, V, in a region of space depends on position, x, as shown. In which of the five indicated regions does the electric field have its maximum magnitude?

(a) In region *iv*.
(b) In region *i*.
(c) In region *ii*.
(d) In region *iii*.
(e) In region *v*.



7. (8 points) Three positively-charged particles, two with charge $+Q$ and one with charge $+q$ are arranged as shown. Each has mass m. The particles with charge $+Q$ are held in place, while the particle with charge $+q$ is released from rest. What is the speed of the particle with charge $+q$ when it is very far from the other particles?

(a) $v = \sqrt{4\frac{K}{m}\frac{Qq}{d}}$ (b) $v = \sqrt{\frac{K}{m}\frac{Qq}{d}}$ (c) $v = \sqrt{2\frac{K}{m}\frac{Qq}{d}}$ (d) $v = \infty$ (e) $v = \sqrt{3\frac{K}{m}\frac{Qq}{d}}$