first (given)	*last (family)*	**Physics 2212 G**

Name, *printed* as it appears in Canvas

Spring 2022

Nine-digit Tech ID

Quiz
3A

- **Print** your name and nine-digit Tech ID *very neatly* in the spaces above.
- Free-response problems are numbered I–III. Show all your work clearly, including all steps and logic. Write **darkly**. Blue or black ink is recommended. Do not make any erasures in your free-response work. Cross out anything you do not want evaluated. Box your answer.
- Multiple-choice questions are numbered 1–8. For each, select the answer most nearly correct, circle it on your quiz, and fill the bubble for your answer on this front page.
- Initial the odd pages in the top margin, in case the pages of your quiz get separated.
- The standard formula sheet is on the back of this page, which may be removed from the quiz form if you wish, but it must be submitted.
- If the page for a free-response problem has insufficient space for your work, ask a proctor for an additional sheet. If you wish this work to be evaluated, put your name on the sheet and make a note on the problem page, so graders will know where to look for your work.
- You may use a calculator that cannot store letters, but no other aids or electronic devices.
- Your score will be posted when your quiz has been graded. Quiz grades become final when the next quiz is administered.

Fill in bubbles for your Multiple Choice answers darkly and neatly.

	a	b	c	d	e
1	(a)	(b)	(c)	(d)	(e)
2	(a)	(b)	(c)	(d)	(e)
3	(a)	(b)	(c)	(d)	(e)
4	(a)	(b)	(c)	(d)	(e)
5	(a)	(b)	(c)	(d)	(e)
6	(a)	(b)	(c)	(d)	(e)
7	(a)	(b)	(c)	(d)	(e)
8	(a)	(b)	(c)	(d)	(e)
	a	b	c	d	e

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

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

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

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

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

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

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

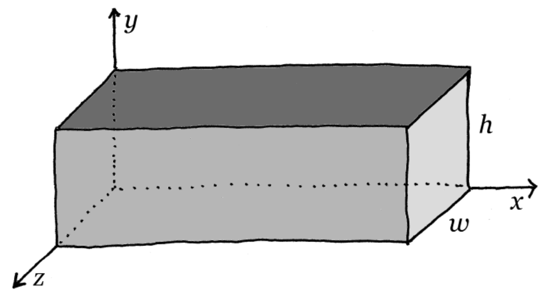
Unless otherwise directed, friction, drag, and gravity should be neglected, all batteries and wires are ideal, and all derivatives and integrals in free-response problems must be evaluated.

You may remove this sheet from your Quiz or Exam

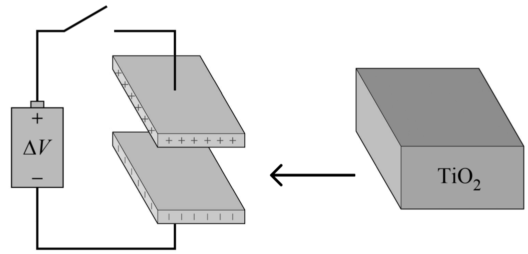
I. (16 points) An infinite straight wire with rectangular cross-section lies with one edge on the x axis, a segment of which is shown in the figure. It has height h in the y direction, and carries a non-uniform current density $\vec{J}$ that varies according to

$$\vec{J} = J_0 \left(\frac{z}{h}\right) \hat{\imath}$$

where J_0 is a positive constant. If the wire carries a total current I_0, what is the width w of the wire in terms of parameters defined the problem and physical or mathematical constants?



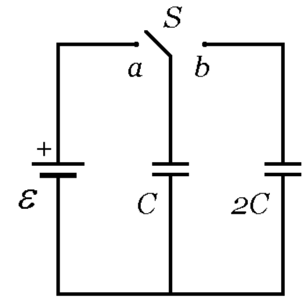
1. (6 points) A parallel-plate capacitor has plates of area $A = 0.25\,\mathrm{m}^2$ and separation $s = 2.4\,\mathrm{mm}$. A battery charges it to a potential difference of 845 V, and is then disconnected. A 2.55 kg slab of titanium dioxide (dielectric constant 110) is shaped to exactly fill the gap between the plates. The slab will be released from rest outside the capacitor. What remains the same as the slab moves into the gap between the plates?



(a) The charge magnitude on each capacitor plate.
(b) The charge magnitude on each capacitor plate, *and* the electric field between the capacitor plates.
(c) The electric field between the capacitor plates.
(d) The potential difference between the capacitor plates.
(e) The potential difference between the capacitor plates, *and* the electric field between the capacitor plates.

II. (16 points) In the problem above, what maximum speed does the slab have as it passes between the plates?

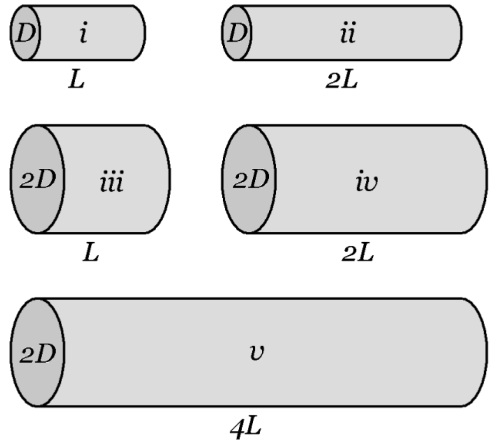
III. (16 points) The emf of the battery in the illustrated circuit is $\mathcal{E}$. The capacitor on the left has capacitance C and that on the right has capacitance $2C$. The switch S is placed in position a for a long time, then thrown to position b. Once equilibrium is reached, and with respect to zero energy stored in an uncharged capacitor, what is the energy stored in the capacitor on the right? Express your answer in terms of parameters defined in the problem and physical or mathematical constants.



2. (6 points) In the problem above, how does the total energy stored in both capacitors while the switch is in position a compare to the total energy stored in both capacitors when the switch is in position b?

   (a) The total energy with the switch in position a is **the same as** the total with the switch in position b.
   (b) The total energy with the switch in position a is **the opposite of** the total with the switch in position b.
   (c) The total energy with the switch in position a is **greater than** the total with the switch in position b.
   (d) The relative energy stored in the two situations **cannot be determined** with the information provided.
   (e) The total energy with the switch in position a is **less than** the total with the switch in position b.

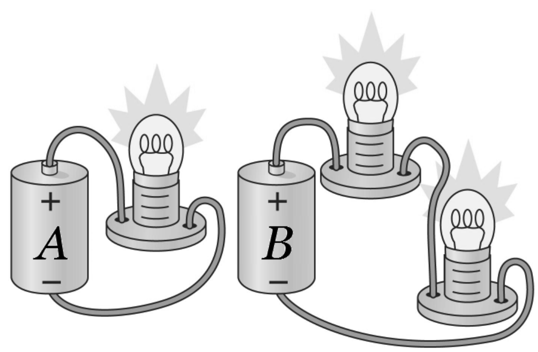
3. (7 points) When a particular potential difference ΔV_0 is applied across the length of each of the wire segments shown, the same current I_0 flows through each segment. Segment i has length L and diameter D. Rank the resistivities of the segments from *greatest* to *least*.



(a) $i = ii = iii = iv = v$
(b) $ii = v > i = iv > iii$
(c) $ii > i = v > iv > iii$
(d) $iii > iv > i = v > ii$
(e) $iii > i = iv > ii = v$

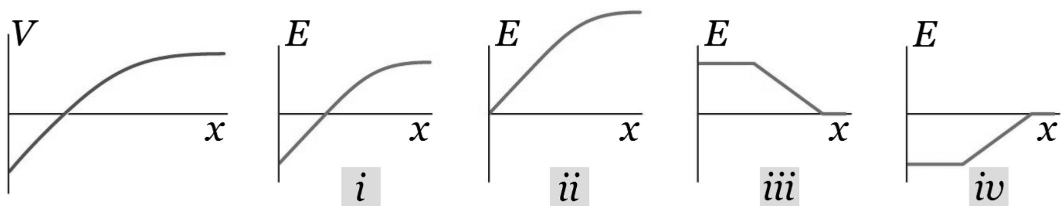
4. (7 points) The two circuits shown are constructed of two identical batteries and three identical light bulbs. All the bulbs are glowing. Compare the potential differences ΔV across the terminals of the two batteries, and the currents I supplied by the two batteries.

(a) $\Delta V_A = \Delta V_B$, and $I_A = I_B$.
(b) $\Delta V_A = \Delta V_B$, and $I_A > I_B$.
(c) $\Delta V_A < \Delta V_B$, and $I_A = I_B$.
(d) $\Delta V_A > \Delta V_B$, and $I_A > I_B$.
(e) $\Delta V_A < \Delta V_B$, and $I_A < I_B$.



5. (6 points) The graph on the left below shows an electric potential as a function of position in one dimension. Which of the graphs i through iv shows the corresponding electric field as a function of position?

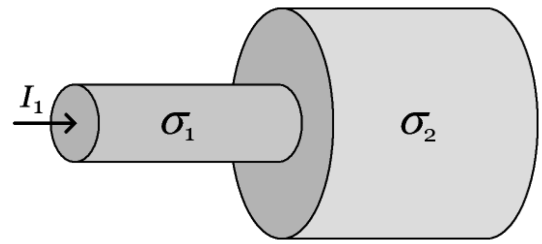
   (a) Only graph i.
   (b) Only graph ii.
   (c) Only graph iv.
   (d) Only graph iii.
   (e) Both graphs i and ii show possible fields.



6. (6 points) In the problem above, what is the direction of the electric field at the location where the electric potential is zero (that is, where the electric potential graph crosses the x axis)?

   (a) The electric field points in the $-x$ direction.
   (b) The electric field has no direction at that location, regardless of its magnitude.
   (c) The electric field has no direction at that location, as its magnitude is zero.
   (d) The electric field points in the $+x$ direction.
   (e) The electric field is perpendicular to the electric potential, but cannot be further specified from the information provided.

7. (7 points) The illustrated wire is composed of two segments, 1 and 2, having different conductivities σ_1 and σ_2, and different radii R_1 and R_2. The conductivity of segment 2 is only half the conductivity of segment 1. The radius of segment 2 is three times the radius of segment 1. What is the ratio of the electric field magnitude in segment 1 to that in segment 2, E_1/E_2?



(a) $E_1/E_2 = 2/3$
(b) $E_1/E_2 = 9/2$
(c) $E_1/E_2 = 3/2$
(d) $E_1/E_2 = 1$
(e) $E_1/E_2 = 2/9$

8. (7 points) An ideal parallel-plate capacitor is attached to a battery and allowed to achieve electrostatic equilibrium. Insulating handles are then used to push the plates closer together *while the capacitor remains connected to the battery*, until their spacing is half the original spacing. How does the potential energy stored in the capacitor with this new spacing, U_{new}, compare to that stored in the capacitor with the original spacing, U_0? (Let the potential energy stored in the uncharged capacitor be zero.)

(a) $U_{\text{new}} = U_0$ (b) $U_{\text{new}} = 4U_0$ (c) $U_{\text{new}} = 2U_0$ (d) $U_{\text{new}} = U_0/4$ (e) $U_{\text{new}} = U_0/2$