Canvas Name, Printed

**Physics 2212 G**

Spring 2019

Nine-digit Tech ID

Quiz #
2A

- **Print** your "Canvas 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 1–7. 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 is given.

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

| | a | b | c | d | e |
|---|---|---|---|---|---|
| 1 | ⓐ | ⓑ | ⓒ | ⓓ | ⓔ |
| 2 | ⓐ | ⓑ | ⓒ | ⓓ | ⓔ |
| 3 | ⓐ | ⓑ | ⓒ | ⓓ | ⓔ |
| 4 | ⓐ | ⓑ | ⓒ | ⓓ | ⓔ |
| 5 | ⓐ | ⓑ | ⓒ | ⓓ | ⓔ |
| 6 | ⓐ | ⓑ | ⓒ | ⓓ | ⓔ |
| 7 | ⓐ | ⓑ | ⓒ | ⓓ | ⓔ |
| | 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 :

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

Parallel :

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

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

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

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

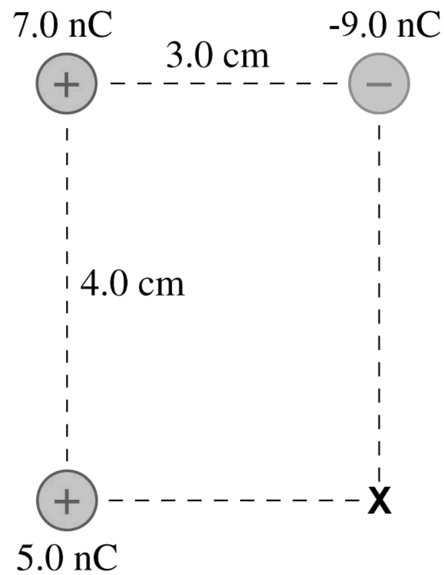
Fundamental Charge $e = 1.602\times10^{-19}\,\text{C}$
Earth's gravitational field $g = 9.81\,\text{N/kg}$
Coulomb constant $K = 8.988\times10^{9}\,\text{N}\cdot\text{m}^2/\text{C}^2$
Speed of Light $c = 2.998\times10^{8}\,\text{m/s}$

Mass of an Electron $m_{\text{e}} = 9.109\times10^{-31}\,\text{kg}$
Mass of a Proton $m_{\text{p}} = 1.673\times10^{-27}\,\text{kg}$
Vacuum Permittivity $\epsilon_0 = 8.854\times10^{-12}\,\text{C}^2/\text{N}\cdot\text{m}^2$
Vacuum Permeability $\mu_0 = 4\pi\times10^{-7}\,\text{T}\cdot\text{m/A}$

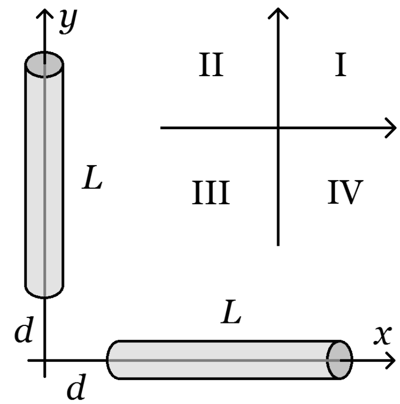
*Unless otherwise directed, friction, drag, and gravity should be neglected, and all batteries and wires are ideal.*
*All derivatives and integrals in free-response problems must be evaluated.*

*You may remove this sheet from your Quiz or Exam*

*I*. (16 points) A system of three charged particles is arranged on the corners of a rectangle, as shown. How much work must an external agent do move the particle with $-9.0\,\mathrm{nC}$ of charge from rest at the upper right (where it is pictured) to rest at the lower right (marked with an "X")?



1. (6 points) Two identical, thin, insulating rods with length $L$ are placed on the $x$ and $y$ axes at $x = d$ and $y = d$, as shown. Their linear charge densities $\lambda$ depend on position according to



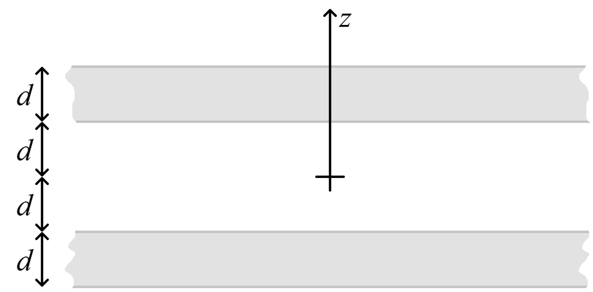

$$\text{rod on } x: \quad \lambda_x = \lambda_0 \frac{x}{L} \qquad\qquad \text{rod on } y: \quad \lambda_y = \lambda_0 \frac{y}{L}$$

where $\lambda_0$ is a constant. What is the direction of the electric potential at the origin?

(a) Quadrant $I$ if $\lambda_0$ is positive, quadrant $III$ if $\lambda_0$ is negative.
(b) Quadrant $II$ if $\lambda_0$ is positive, quadrant $IV$ if $\lambda_0$ is negative.
(c) Quadrant $IV$ if $\lambda_0$ is positive, quadrant $II$ if $\lambda_0$ is negative.
(d) No direction.
(e) Quadrant $III$ if $\lambda_0$ is positive, quadrant $I$ if $\lambda_0$ is negative.

$II$. (16 points) In the problem above, what is 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.

*III.* (16 points) Two identical infinite insulating slabs have thickness $d$ and uniform volume charge density $\rho$. They are separated by a distance $2d$, as shown. Find an expression for the electric field magnitude within the top slab as a function of distance $z$ from the center of the gap (that is, for $d < z < 2d$), in terms of parameters defined in the problem, and physical or mathematical constants.



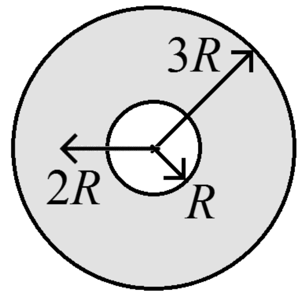

2. (6 points) In the problem above, describe the electric field magnitude between the slabs ($-d < z < d$). Describe the field magnitude beyond the slabs ($|z| > 2d$).

   (a) Field magnitude is non-zero constant between the slabs. It is zero beyond the slabs.
   (b) Field magnitude is zero between the slabs. It is a non-zero constant beyond the slabs.
   (c) Field magnitude is zero between the slabs. It is zero beyond the slabs.
   (d) Field magnitude is non-zero constant between the slabs. It is the same non-zero constant beyond the slabs.
   (e) Field magnitude is non-zero constant between the slabs. It is a different non-zero constant beyond the slabs.

3. (8 points) A hollow insulating sphere has inner radius $R$, outer radius $3R$, and uniform volume charge density $\rho$. If Gauss' Law is used to find the magnitude of the electric field $E$ at a distance $2R$ from the center, the Gaussian Surface may be chosen so

$$\epsilon_0 \oint \vec{E} \cdot d\vec{A} = q_{\text{in}} \qquad \Rightarrow \qquad \epsilon_0 E A = \rho V \qquad \Rightarrow \qquad E = \frac{\rho V}{\epsilon_0 A}$$

With this approach, what is $A$? What is $V$?




(a) $A = 4\pi\,(2R)^2$ and $V = \frac{4}{3}\pi\,7R^3$
(b) $A = 4\pi\,(3R)^2$ and $V = \frac{4}{3}\pi\,19R^3$
(c) $A = 4\pi\,(2R)^2$ and $V = \frac{4}{3}\pi\,26R^3$
(d) $A = 4\pi\,(3R)^2$ and $V = \frac{4}{3}\pi\,8R^3$
(e) $A = 4\pi R^2$ and $V = \frac{4}{3}\pi\,27R^3$

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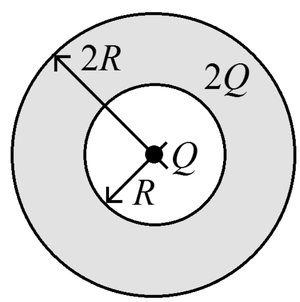
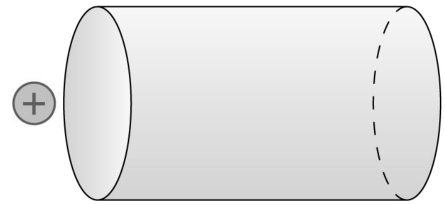
4. (8 points) A hollow conducting sphere has inner radius $R$ and outer radius $2R$. It carries a charge $2Q$. Centered within it lies a particle with charge $Q$. Compare the area charge densities on the inner ($\eta_{\text{in}}$) and outer ($\eta_{\text{out}}$) surfaces of the sphere.



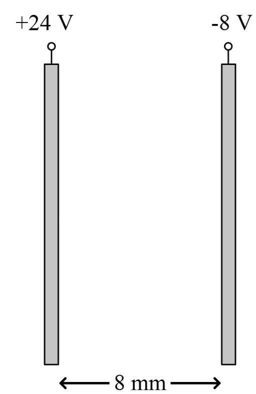

(a) $|\eta_{\text{out}}| > |\eta_{\text{in}}|$, because $\eta_{\text{in}} = 0$.
(b) $|\eta_{\text{out}}| < |\eta_{\text{in}}|$. $\eta_{\text{in}}$ and $\eta_{\text{out}}$ have opposite signs.
(c) $|\eta_{\text{out}}| < |\eta_{\text{in}}|$. $\eta_{\text{in}}$ and $\eta_{\text{out}}$ have the same sign.
(d) $|\eta_{\text{out}}| > |\eta_{\text{in}}|$. $\eta_{\text{in}}$ and $\eta_{\text{out}}$ have the same sign.
(e) $|\eta_{\text{out}}| = |\eta_{\text{in}}|$. $\eta_{\text{in}}$ and $\eta_{\text{out}}$ have opposite signs.

5. (8 points) A positively charged particle lies outside a finite cylinder, on its axis, as shown. Compare the electric fluxes through the left ($\Phi_L$) and right ($\Phi_R$) end caps of the cylinder.



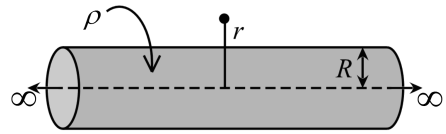
(a) $\Phi_L$ and $\Phi_R$ have opposite signs, with $|\Phi_R| < |\Phi_L|$.
(b) $\Phi_L$ and $\Phi_R$ have the same sign, with $|\Phi_R| < |\Phi_L|$.
(c) $\Phi_L$ and $\Phi_R$ have opposite signs, with $|\Phi_R| > |\Phi_L|$.
(d) $\Phi_L$ and $\Phi_R$ have opposite signs, with $|\Phi_R| = |\Phi_L|$.
(e) $\Phi_L$ and $\Phi_R$ have the same sign, with $|\Phi_R| > |\Phi_L|$.

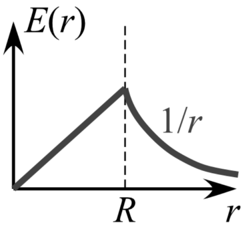
6. (8 points) The plates of an ideal parallel-plate capacitor are 8.0 mm apart. The negative plate is at -8.0 V, while the positive plate is at +24 V. What is the electric potential inside the capacitor, at a point 2.0 mm from the negative plate?

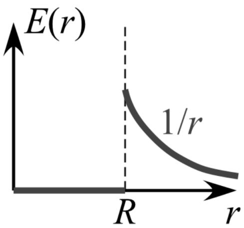


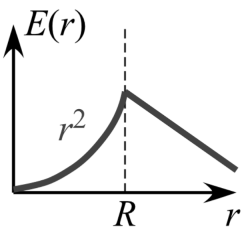

(a) -2.0 V
(b) +6.0 V
(c) -6.0 V
(d) +2.0 V
(e) 0 V

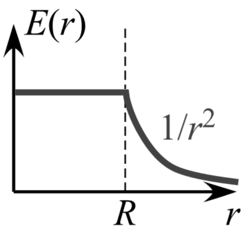
7. (8 points) An infinite insulating cylinder has radius $R$ and uniform volume charge density $\rho$. Which graph below best represents the magnitude of the electric field $E\,(r)$ as a function of the distance $r$ from the cylinder axis?




(a)



(b)



(c)



(d)



(e)