first (given)	last (family)	Nine-digit Tech ID

Name, *printed* as it appears in Canvas

Physics 2211 G

Spring 2022

Quiz

2A

- **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	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ
2	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ
3	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ
4	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ
5	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ
6	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ
7	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ
8	ⓐ	ⓑ	ⓒ	ⓓ	ⓔ
	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 :
$$\frac{1}{C_{\mathrm{eq}}} = \sum \frac{1}{C_i}$$
$$R_{\mathrm{eq}} = \sum R_i$$

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

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

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

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

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

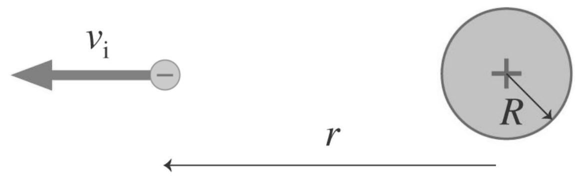
Mass of an Electron $m_{\mathrm{e}} = 9.109\times10^{-31}\,\mathrm{kg}$
Mass of a Proton $m_{\mathrm{p}} = 1.673\times10^{-27}\,\mathrm{kg}$
Vacuum Permittivity $\epsilon_0 = 8.854\times10^{-12}\,\mathrm{C^2/N{\cdot}m^2}$
Vacuum Permeability $\mu_0 = 4\pi\times10^{-7}\,\mathrm{T{\cdot}m/A}$

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.

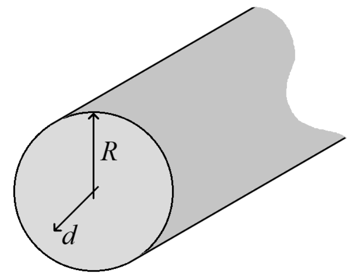
You may remove this sheet from your Quiz or Exam

I. (16 points) An electron is at a distance r from the center of a spherical bead of radius $R < r$ and uniformly distributed positive charge $+Q$. It has an initial velocity directed straight away from the bead.

For what maximum initial speed v_{max} will the electron eventually strike the bead? If the electron will always or never strike the bead, prove that $v_{\text{max}} = 0$ or $v_{\text{max}} = \infty$. Otherwise, express your answer in terms of parameters defined in the problem, and physical or mathematical constants.



II. (16 points) Consider an infinitely long solid insulating cylinder with radius R that carries a volume charge density ρ that depends on distance r from the central axis, according to



$$\rho(r) = \rho_0 r/R$$

where ρ_0 is a constant.

Find the magnitude of the electric field at a point inside the cylinder, that is, at a distance d from the axis, where $d < R$. Express your answer in terms of parameters defined in the problem, and physical or mathematical constants.

1. (6 points) Consider a point outside the cylinder in the above problem, at a distance D from the cylinder axis, where $D > R$. On what distances does the magnitude of the electric field at that point depend?

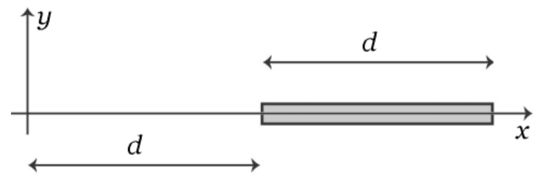
   (a) D, R, and d only.
   (b) D and R only.
   (c) D, R, d, and r.
   (d) D and d only.
   (e) D, R, and r only.

III. (16 points) A thin rod of length d lies on the x axis with one end at $x = d$, as illustrated. The linear charge density, λ, of the rod depends on position, x, according to

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

where λ_0 is a positive constant.

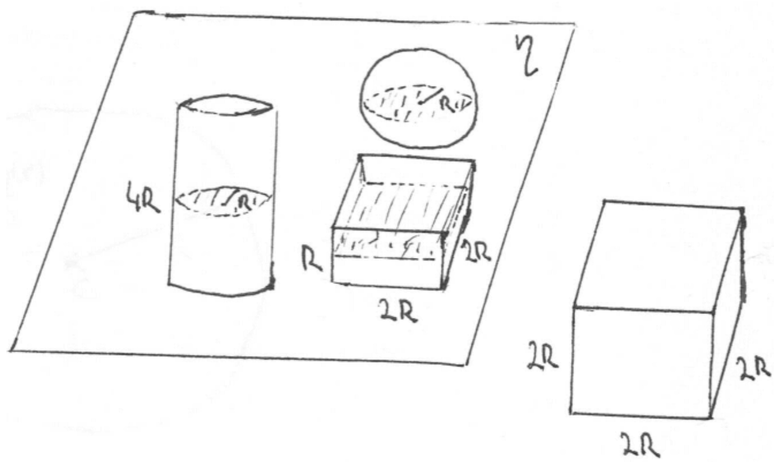
What is the electric potential at the origin, with respect to zero at infinity? Express your answer in terms of parameters defined in the problem, and physical or mathematical constants.



2. (6 points) In the problem above, what is the direction of the electric potential at the origin?
   (a) The electric potential at the origin is in the $+x$ or $+\hat{\imath}$ direction.
   (b) The electric potential at the origin is in the $-x$ or $-\hat{\imath}$ direction.
   (c) This is not a meaningful question.
   (d) The electric potential at the origin has no direction, because its magnitude is zero.
   (e) More information is needed to determine the direction of the electric potential at the origin.

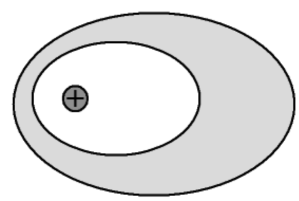
3. (7 points) A plane with positive uniform area charge density η passes through the centers of three closed surfaces (a sphere of radius R, a cylinder of radius R and height $4R$, and a rectangular prism with height R and square base of edge $2R$), as illustrated. The cube with edge $2R$ does not intersect the plane. Rank the electric flux, Φ, through these surfaces from greatest to least.

(a) $\Phi_{\text{prism}} > \Phi_{\text{cylinder}} > \Phi_{\text{sphere}} > \Phi_{\text{cube}}$
(b) $\Phi_{\text{cylinder}} > \Phi_{\text{sphere}} > \Phi_{\text{cube}} > \Phi_{\text{prism}}$
(c) $\Phi_{\text{prism}} > \Phi_{\text{cylinder}} = \Phi_{\text{sphere}} > \Phi_{\text{cube}}$
(d) $\Phi_{\text{sphere}} > \Phi_{\text{cylinder}} > \Phi_{\text{prism}} > \Phi_{\text{cube}}$
(e) $\Phi_{\text{cylinder}} > \Phi_{\text{sphere}} > \Phi_{\text{prism}} > \Phi_{\text{cube}}$

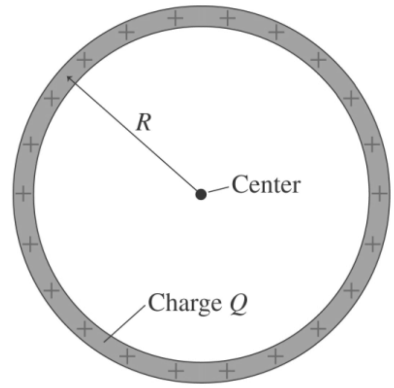


4. (7 points) A hollow conductor, illustrated in cross-section, carries a net charge of -3 nC. Within its void lies a particle with a charge of +5 nC. What is the net charge on the inner and outer surfaces of the conductor at equilibrium?

(a) $Q_{\text{inner}} = -5\,\text{nC}$ while $Q_{\text{outer}} = +5\,\text{nC}$
(b) $Q_{\text{inner}} = 0\,\text{nC}$ while $Q_{\text{outer}} = -3\,\text{nC}$
(c) $Q_{\text{inner}} = -3\,\text{nC}$ while $Q_{\text{outer}} = 0\,\text{nC}$
(d) $Q_{\text{inner}} = -5\,\text{nC}$ while $Q_{\text{outer}} = +2\,\text{nC}$
(e) $Q_{\text{inner}} = -5\,\text{nC}$ while $Q_{\text{outer}} = -3\,\text{nC}$



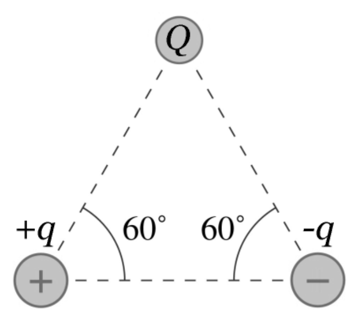
5. (7 points) A thin insulating ring has total charge Q and radius R. What is the electric potential at its center, with respect to zero at infinity?



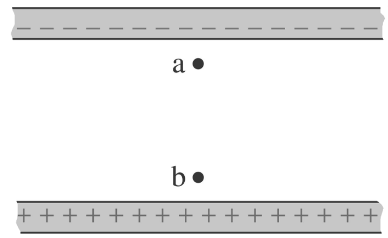
   (a) $2\pi KQ$
   (b) KQ/R
   (c) The electric potential is undefined at the center.
   (d) KQ/R^2
   (e) Zero.

6. (7 points) A system consists of three charged particles at the vertices of an equilateral triangle, as illustrated. Two of the particles have charge of equal magnitude, q, but opposite sign. The third particle has charge Q. How does the electric potential energy of the system change if the particle with charge Q is removed to infinitely far away?

   (a) It increases if Q is positive, but decreases if Q is negative.
   (b) It increases.
   (c) It decreases.
   (d) It increases if Q is negative, but decreases if Q is positive.
   (e) It remains the same.



7. (6 points) Two points, a and b, are pictured within an ideal parallel-plate capacitor. If an *electron* moves from point a to point b, how does the *electric potential energy* of the capacitor-electron system change?



   (a) The electric potential energy of the system remains the same.
   (b) The sign of the system's electric potential energy change cannot be determined from the information provided.
   (c) The electric potential energy of the system decreases.
   (d) The electric potential energy of the system increases.
   (e) This is not a meaningful question.

8. (6 points) In the problem above, compare the *electric potential* at point a when the electron is located there, to the electric potential at point b when the electron is located there.

   (a) The electric potential at point a is the same as at point b.
   (b) The electric potential at point a is less than that at point b.
   (c) This is not a meaningful question.
   (d) The electric potential at point a is greater than that at point b.
   (e) The relative values of the electric potential at points a and b cannot be determined from the information provided.