Name

Nine-digit Tech ID

Fall 2018 **Physics 2212 GJ** Quiz #

# 2A

- Put *nothing* other than your name and nine-digit Tech ID 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 know where to find 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.*

1 ⓐ ⓑ ⓒ ⓓ ⓔ

2 ⓐ ⓑ ⓒ ⓓ ⓔ

3 ⓐ ⓑ ⓒ ⓓ ⓔ

4 ⓐ ⓑ ⓒ ⓓ ⓔ

5 ⓐ ⓑ ⓒ ⓓ ⓔ

6 ⓐ ⓑ ⓒ ⓓ ⓔ

7 ⓐ ⓑ ⓒ ⓓ ⓔ

# 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 :

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

$$\vec{E} = k\frac{q}{r^2}\hat{r}$$
$$\vec{F} = k\frac{q_1q_2}{r^2}\hat{r}$$
$$\vec{F} = q\vec{E}$$
$$\vec{p} = q\vec{d}$$
$$\vec{\tau} = \vec{p}\times\vec{E}$$
$$U = -\vec{p}\cdot\vec{E}$$
$$|\vec{E}| \propto \frac{|\vec{p}|}{r^3}$$
$$\Phi_{\rm E} = \int \vec{E}\cdot d\vec{A}$$
$$\epsilon_0 \oint \vec{E}\cdot d\vec{A} = q_{\rm enclosed}$$
$$\oint \vec{E}\cdot d\vec{\ell} = -\frac{d\Phi_{\rm B}}{dt}$$
$$C = \frac{Q}{\Delta V}$$
$$C = \epsilon_0\frac{A}{d}$$
$$U = \tfrac{1}{2}C\,[\Delta V]^2$$
$$R = \rho\frac{\ell}{A}$$
$$\tau_{\rm C} = RC$$
$$u_{\rm E} = \tfrac{1}{2}\epsilon_0 E^2$$

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

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

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, and all batteries and wires are ideal.*
*All derivatives and integrals in free-response problems must be evaluated.*

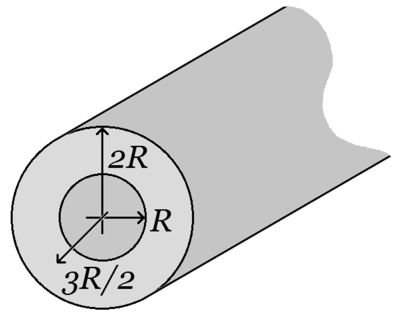
*You may remove this sheet from your Quiz or Exam*

*I*. (16 points) Consider the Bohr model of a hydrogen atom, an electron in a circular orbit about a proton. The radius of the orbit is $52.9 \times 10^{-12}\,\mathrm{m}$. What minimum speed would the electron need to have for it to leave orbit and never return. If there is no such speed (that is, if the minimum speed is infinite), prove it.

*II*. (20 points) An infinite hollow insulating cylinder has inner radius $R$ and outer radius $2R$, as illustrated. Its volume charge density, $\rho$, varies with distance $r$ from the center according to

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

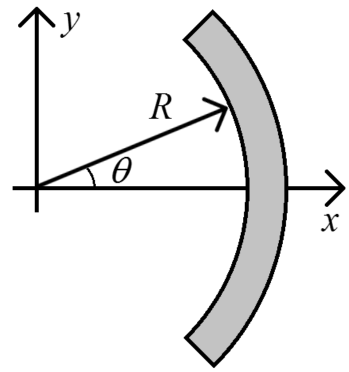
where $\rho_0$ is a positive constant. Find the electric field magnitude at a distance $3R/2$ from the center in terms of parameters defined in the problem, and physical or mathematical constants.




1. (6 points) In the problem above, what is the direction of the electric field at a distance $3R/2$ from the center?

   (a) Into the page.
   (b) Toward the center.
   (c) Away from the center.
   (d) This is not a meaningful question.
   (e) Out of the page.

2. (6 points) A non-uniform thin rod of charge is bent into an arc of radius $R$. It extends from $\theta = -\pi/4$ to $\theta = +\pi/4$, as shown. The linear charge density $\lambda$ of the rod depends on angle $\theta$ according to




$$\lambda = \lambda_0 \theta^2$$

where $\lambda_0$ is a positive constant and $\theta$ is in radians. In what direction is the electric potential at the origin?

(a) In the $+y$ direction.
(b) This is not a meaningful question.
(c) In the $-x$ direction.
(d) In the $-y$ direction.
(e) In the $+x$ direction.

*III*. (16 points) In the problem above, 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.

3. (8 points) The field outside a uniformly charged infinite solid cylinder of radius $R$ is identical to that of an infinite line with equal linear charge density,

$$E = \frac{2K\lambda}{r}$$

when the distance from the central axis, $r$, is greater than or equal to $R$. If it can be determined, what is the electric field like *inside* the cylinder?

(a) The field is also given by the infinite line expression, $2K\lambda/r$ for $r$ between zero and $R$, inclusive.
(b) There is no way to tell, since Gauss' Law isn't valid *inside* charge distributions.
(c) The field is constant inside, having the same value everywhere that is does at the surface, $2K\lambda/R$.
(d) The field increases linearly from zero at the center to $2K\lambda/R$ at the surface.
(e) The field is zero inside, and jumps discontinuously to $2K\lambda/R$ at the surface.

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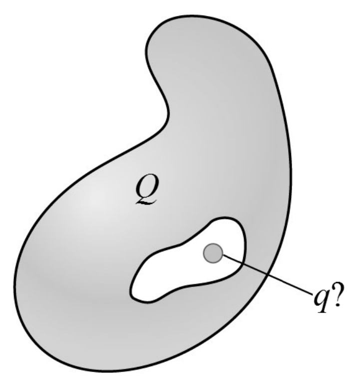
4. (8 points) A conducting solid object has a bubble or void within it (**NOT** a hole drilled through it!). If the object has a charge $Q$, what charge $q$, if any, could be placed within the void to make the charges on the inner and outer surfaces of the object equal to each other?

(a) $q = Q/2$
(b) $q = Q$
(c) $q = -Q$
(d) No possible charge $q$ could accomplish that.
(e) $q = -Q/2$

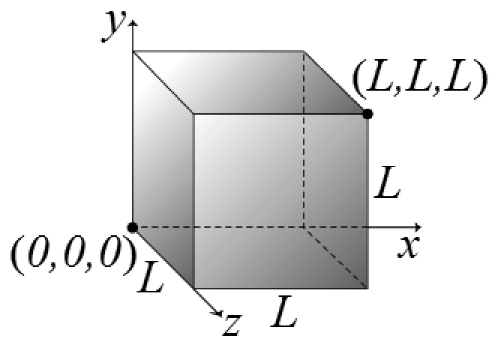


5. (8 points) A cube with sides of length $L$ is positioned with one corner at the origin and its edges aligned with the $xyz$-axes as shown. There is a non-uniform electric field

$$\vec{E} = E_x\,\hat{\imath} - E_y\left(\frac{y}{L}\right)\hat{\jmath}$$

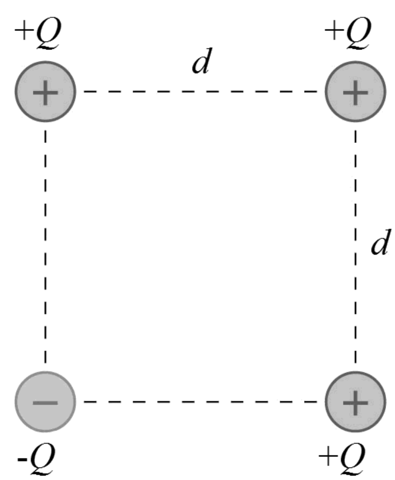
where $E_x$ and $E_y$ are positive constants. What is the net electric flux through the cube?

(a) Zero
(b) $(E_x\,\hat{\imath} - E_y\,\hat{\jmath})\,L^2$
(c) $(E_x - E_y)\,L^2$
(d) $-E_y L^2\,\hat{\jmath}$
(e) $-E_y L^2$




6. (16 points) Four point particles are arranged on the corners a square, as shown. Each has the same charge magnitude $Q$, but three are positive while one is negative. If the square has sides of length $d$, what is the electric potential energy of the system of four charges, with respect to zero at infinite separation?

(a) $2KQ^2/d$
(b) $\left(2+\sqrt{2}\right)KQ^2/d$
(c) $4KQ^2/d$
(d) $\left(4-2\sqrt{2}\right)KQ^2/d$
(e) Zero



7. (8 points) A positively charged particle is placed against the positive plate of an ideal capacitor and released from rest. After it has traveled one-third the distance $d$ across the capacitor, it has speed $v_0$. With what speed does it strike the negative plate?

(a) $4v_0$
(b) $2v_0$
(c) $v_0\sqrt{2}$
(d) $v_0\sqrt{3}$
(e) $3v_0$