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**PHYS 2135 Exam I**
September 18, 2018

Name: ____________________________

For questions 1-5, select the best answer. For problems 6-9, solutions must begin with an Official Starting Equation, when appropriate. Work must be shown to receive credit. Calculators are not allowed.

(8) ___**C**_____ 1. A Gaussian sphere of radius *R* is centered on a positive charge *Q*. If the radius of the sphere is doubled the net electric flux through the Gaussian surface is …

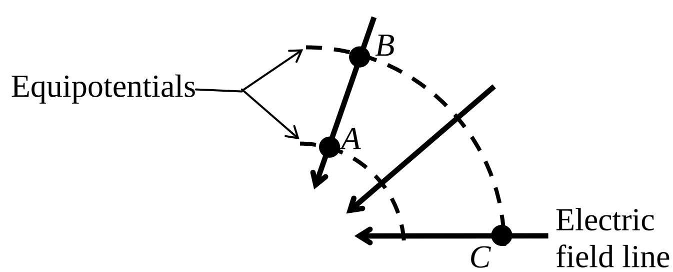
[A] doubled
[B] halved
[C] unchanged
[D] reduced by a factor of four

(8) ___**B**_____ 2. You are given three charged insulating spheres. Spheres 1 and 2 are found to attract each other. Spheres 2 and 3 are found to repel each other. Which of the following can you conclude?

[A] Spheres 1 and 3 carry charges of equal sign
[B] Spheres 1 and 3 carry charges of opposite sign
[C] All three spheres carry charges of the same sign
[D] Spheres 1 and 3 will repel each other

(8) ___**B**_____ 3. The figure shows the electric field lines and equipotentials in a certain region of space. Which of the following is true?

[A] $V_A > V_B$ and $V_B = V_C$
[B] $V_B > V_A$ and $V_B = V_C$
[C] $V_C > V_B$ and $V_A = V_B$
[D] $V_A = V_B = V_C$




(8) ___**B**_____ 4. The capacitance of a parallel-plate capacitor can be increased …

[A] by increasing charge on each plate.
[B] by increasing the area of each plate.
[C] by increasing spacing between the plates.
[D] by increasing the potential difference across the plates.

(8) _________ 5. What do the San Diego Chargers have in common with PHYS 2135 students?

[A] Great Potential [B] Field Lines
[C] Formulas for Success [D] More Points

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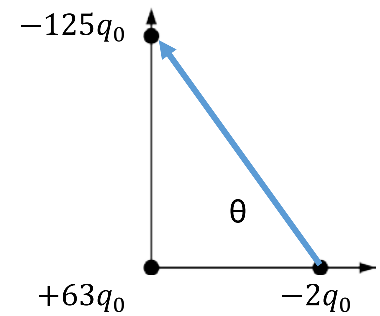
**6.** There is a positive charge $+63q_0$ at the origin and a negative charge $-125q_0$ located at (x,y) = (0, 4*a*). Start with an OSE and express your answers in terms of *k*, $q_0$, *m* and the given quantities. For vectors, express your answers in unit vector notation.

(15) (a) What is the electric field at (x,y) = (3*a*, 0) due to the $+63q_0$ charge?




$$\vec{E} = k\frac{q}{r^2}\hat{r}$$

$$\vec{E}_{63} = \frac{k(63q_0)}{(3a)^2}\hat{\imath}$$

$$\vec{E}_{63} = \frac{7kq_0}{a^2}\hat{\imath}$$

(15) (b) What is the electric field at (x,y) = (3*a*, 0) due to the $-125q_0$ charge?

$$\vec{E}_{125} = \frac{k(-125q_0)}{(5a)^2}[\cos\theta\hat{\imath} - \sin\theta\hat{\jmath}]$$

$$\sin\theta = \frac{4}{5} \qquad \cos\theta = \frac{3}{5}$$

$$\vec{E}_{125} = \frac{5kq_0}{a^2}\left[-\frac{3}{5}\hat{\imath} + \frac{4}{5}\hat{\jmath}\right]$$

$$\vec{E}_{125} = \frac{kq_0}{a^2}[-3\hat{\imath} + 4\hat{\jmath}]$$

(5) (c) A particle with a negative charge $-2q_0$ and mass *m* is placed at (3*a*, 0). What is the net force on this particle?

$$\vec{E}_{Tot} = \vec{E}_{63} + \vec{E}_{125} = \frac{kq_0}{a^2}[4\hat{\imath} + 4\hat{\jmath}]$$

$$\vec{F} = (-2q_0)\vec{E}_{Tot} = \frac{-8kq_0^2}{a^2}[\hat{\imath} + \hat{\jmath}]$$

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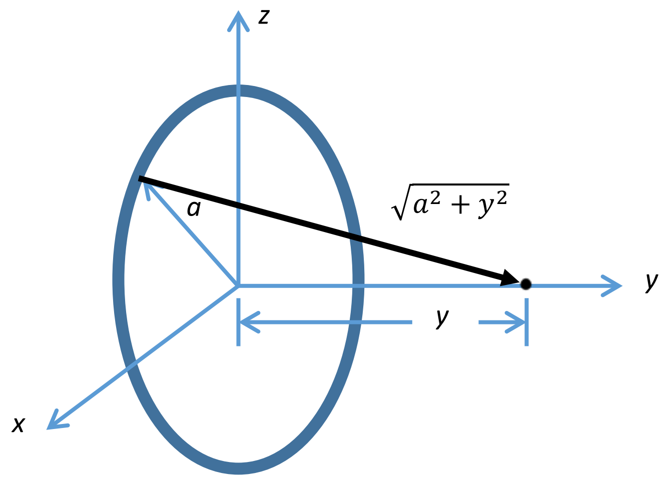
**7.** An insulating ring of radius *a* has a net charge $+Q$ uniformly distributed along the ring. The ring lies in the x-z plane with the origin of the coordinate system at the center of the ring. The *y*-axis is perpendicular to the ring and is on a line through the center of the ring.




(10) (a) Determine the linear charge density $\lambda$ on the ring.

$$\lambda = \frac{Q}{2\pi a}$$

(15) (b) Set up and evaluate an integral to determine the electric potential as a function of *y* along the *y*-axis.

$$V = k\int_0^{2\pi} \frac{dq}{\sqrt{a^2+y^2}} \qquad dq = \lambda a d\theta$$

$$V = k\int_0^{2\pi} \frac{\lambda a d\theta}{\sqrt{a^2+y^2}} = \frac{k\lambda a}{\sqrt{a^2+y^2}}\int_0^{2\pi} d\theta = \frac{2\pi k\lambda a}{\sqrt{a^2+y^2}}$$

$$V = \frac{kQ}{\sqrt{a^2+y^2}}$$

(15) (c) A particle of mass *m* and charge $-q_0$ is placed at $y = 2a$ and released from rest. Determine the speed of the particle as it passes through the center of the ring.

$$E_f - E_i = W_{other} = 0 \qquad U = qV = -q_0V$$

$$U_f + K_f = U_i + \cancel{K_i} \qquad U_f = -\frac{kq_0Q}{a} \qquad U_i = -\frac{kq_0Q}{a\sqrt{5}}$$

$$-\frac{kq_0Q}{a} + \frac{1}{2}mv_f^2 = -\frac{kq_0Q}{a\sqrt{5}}$$

$$v_f = \sqrt{\frac{2}{m}\left(\frac{kq_0Q}{a}\right)\left[1 - \frac{1}{\sqrt{5}}\right]}$$

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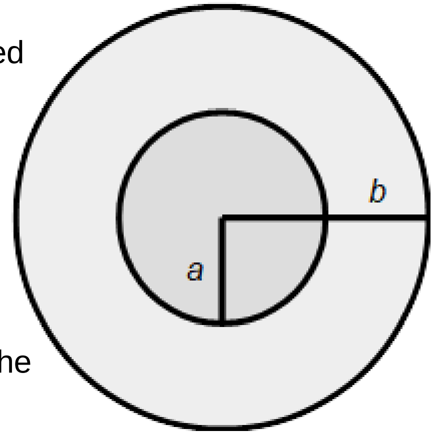
**8.** A solid **insulating** plastic sphere of radius *a* carries a total net negative charge -*Q* uniformly distributed throughout its interior. The insulating sphere is coated with a **conducting** metallic layer in the form of a spherical shell with inner radius *a* and outer radius *b*. The conducting layer carries a net charge of +*Q*.




(5) (a) Compute the volume charge density ρ in the plastic sphere in terms of variables introduced above.

$$\rho = \frac{q}{V} = \frac{-Q}{\frac{4}{3}\pi a^3} = \frac{-3Q}{4\pi a^3}$$

(10) (b) Apply Gauss's law to find the magnitude of the electric field *E(r)* in the region *r* < *a*.

$\oint \vec{E} \cdot d\vec{A} = \frac{q_{enc}}{\epsilon_0}$ $\quad$ $q_{enc} = \rho\left(\frac{4}{3}\pi r^3\right)$ $\quad$ or $\quad$ $q_{enc} = -Q\left(\frac{\frac{4}{3}\pi r^3}{\frac{4}{3}\pi a^3}\right) = -Q\left(\frac{r^3}{a^3}\right)$

$E(4\pi r^2) = \frac{\rho\left(\frac{4}{3}\pi r^3\right)}{\epsilon_0}$ $\quad$ or $\quad$ $E(4\pi r^2) = \frac{-Q\left(\frac{r^3}{a^3}\right)}{\epsilon_0}$

$E = \frac{\rho r}{3\epsilon_0}$ $\quad$ or $\quad$ $|E| = \frac{Qr}{4\pi\epsilon_0 a^3}$

(10) (c) Find the electric field at points in the region *b* > *r* > *a*. Justify your answer.

$E = 0$ $\quad$ *The electric field is zero inside the conductor.*

(10) (d) Find the charge density on the inner surface of the spherical shell.

$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{enc}}{\epsilon_0} = 0$$

$$q_{enc} = 0 = -Q + Q_a$$

$$Q_a = Q$$

$$\sigma_a = \frac{Q_a}{4\pi a^2} = \frac{Q}{4\pi a^2}$$

(5) (e) Find the electric field at points in the region *r* > *b*.

$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{enc}}{\epsilon_0} = \frac{-Q+Q}{\epsilon_0} = 0$$

$$E = 0$$

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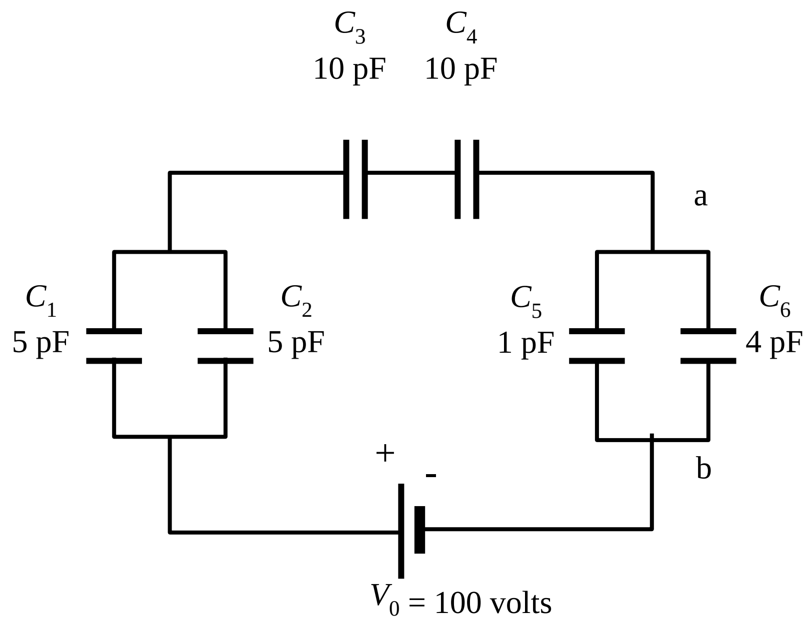
**9.** Consider the given circuit.




(10) (a) Calculate the equivalent capacitance of the entire circuit. (Note: 1 pF = 10 $^{-12}$ F)

$$C_{12} = 5\text{pF} + 5\text{pF} = 10\text{pF}$$

$$C_{56} = 1\text{pF} + 4\text{pF} = 5\text{pF}$$

$$C_{eq} = \left(\frac{1}{10\text{pF}} + \frac{1}{10\text{pF}} + \frac{1}{10\text{pF}} + \frac{1}{5\text{pF}}\right)^{-1}$$

$$C_{eq} = 2\text{pF}$$

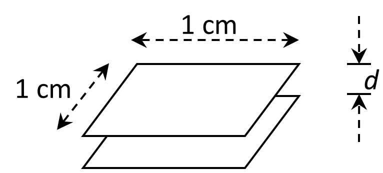
(10) (b) Find the charge $Q_3$ on capacitor $C_3$.

$$Q_3 = Q_{eq} = C_{eq}V_0 = (2\text{pF})(100\text{V}) = 200\text{pC}$$

(10) (c) Find the voltage $V_1$ across capacitor $C_1$.

$$V_{12} = \frac{Q_{12}}{C_{12}} = \frac{Q_{eq}}{C_{12}} = \frac{200\text{pC}}{10\text{pF}} = 20\text{V}$$

(10) (d) Capacitor $C_5$ is a parallel plate capacitor, with the dimensions indicated. Determine the spacing *d* between the plates of this capacitor (a numerical answer is required.)




$$C_5 = \frac{\epsilon_0 A}{d} = \frac{\epsilon_0 L^2}{d}$$

$$d = \frac{\epsilon_0 L^2}{C_5} = \frac{\left(8.85\times10^{-12}\frac{\text{C}^2}{\text{Nm}^2}\right)\left(10^{-2}\text{m}\right)^2}{10^{-12}\text{F}}$$

$$d = 8.85 \times 10^{-4}\text{m}$$