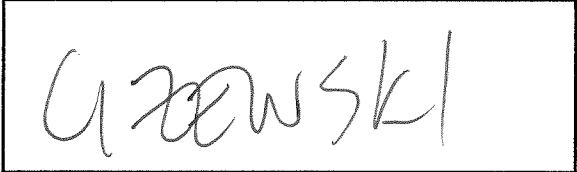


Physics 227 – Hourly Exam 1
Thursday, October 6, 2016, 9:50 PM - 11:10 PM
ARC 103 (Aaa-Jzz), Hill 114 (Kaa-Nzz),
PLH (Oaa-Shz), SEC 111 (Sia-Zzz)

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Your exam code

SIGN HERE

1. Use a #2 pencil to make entries on the answer sheet. *Enter the following ID information now, before the exam starts.*
2. In the section labeled NAME (Last, First, M.I.) enter your last name, then fill in the empty circle for a blank, then enter your first name, another blank, and finally your middle initial.
3. Under STUDENT # enter your 9-digit RUID Number.
4. Under CODE enter the exam code given above.
5. Enter 227 under COURSE. You do not need to write anything else on the answer sheet for now, but you may continue to read the instructions.
6. During the exam, you are allowed one handwritten sheet of paper, 8.5 x 11 inches in size, handwritten on both sides. NO Calculators. NO Cell phones. NO smart watches.
7. The exam consists of 15 multiple-choice questions. For each multiple-choice question mark only **ONE** answer. There is no deduction of points for an incorrect answer, so even if you cannot work out the answer to a question, you should make an educated guess.
8. If you have questions or problems during the exam, you may raise your hand and a proctor will assist you. We will provide the value of physical constants that are needed. It is your responsibility to know the relevant equations.
10. You are not allowed to help any other student, ask for help from anyone but a proctor, change your seat without permission from a proctor or use any electronic device. Doing so will result in a zero score for the exam.
11. **When you are done with the exam, show your student ID to a proctor, hand in only this cover sheet and your answer sheet.**
12. **Please sign above by the name sticker to indicate that you have read and understood these instructions.**

Possibly useful constants:

$$\epsilon_0 = 1/\mu_0 c^2 = 8.85 \times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2$$

$$k = 1/4\pi\epsilon_0 = 8.99 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$$

$$c = \text{speed of light} = 3.00 \times 10^8 \text{ m/s}$$

$$-q_{\text{electron}} = q_{\text{proton}} = 1.602 \times 10^{-19} \text{ C}$$

$$m_{\text{electron}} = \text{electron mass} = 9.11 \times 10^{-31} \text{ kg}$$

$$m_{\text{proton}} = \text{proton mass} = 1.67 \times 10^{-27} \text{ kg}$$

$$1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$$

$$\text{Circumference of a circle} = 2\pi r; \text{ area of a circle is } \pi r^2$$

$$\text{Surface area of a sphere} = 4\pi r^2; \text{ Volume of a sphere} = \frac{4}{3}\pi r^3$$

$$\text{Surface area of a cylinder} = 2\pi r h + 2\pi r^2; \text{ Volume of cylinder} = \pi r^2 h$$

$$\sin(0^\circ) = \cos(90^\circ) = 0$$

$$\sin(90^\circ) = \cos(0^\circ) = 1$$

$$\sin(30^\circ) = \cos(60^\circ) = 1/2$$

$$\sin(60^\circ) = \cos(30^\circ) = \sqrt{3}/2$$

$$\sin(45^\circ) = \cos(45^\circ) = \sqrt{2}/2$$

$$\frac{dx^n}{dx} = nx^{n-1}$$

$$\int x^n = \frac{1}{n+1}x^{n+1} \text{ except when } n = -1. \text{ For } n = -1, \int dx/x = \ln x$$

Some metric prefixes:

$$\text{f} = \text{femto} = 10^{-15}$$

$$\text{p} = \text{pico} = 10^{-12}$$

$$\text{n} = \text{nano} = 10^{-9}$$

$$\mu = \text{micro} = 10^{-6}$$

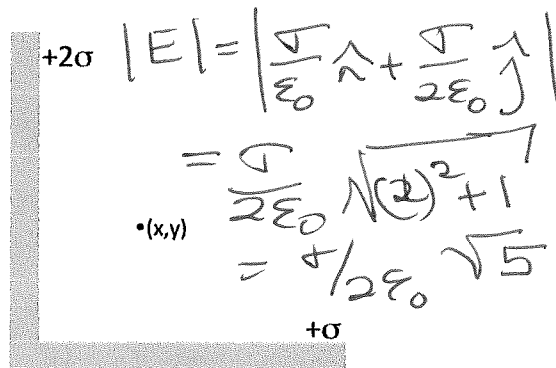
$$\text{m} = \text{milli} = 10^{-3}$$

$$\text{k} = \text{kilo} = 10^3$$

$$\text{M} = \text{mega} = 10^6$$

$$\text{G} = \text{giga} = 10^9$$

1. The figure displays two semi-infinite non-conducting plates. The vertical plate carries a charge per unit area $+2\sigma$; the horizontal plate carries a charge per unit area of $+\sigma$. What is the magnitude of the electric field E at the position (x, y) which is very far away from the sheets and the corner?



- a) $E = \sigma/(2\epsilon_0)$
 b) $E = k\sigma/(\sqrt{x^2 + y^2})$
 c) $E = 3k\sigma/(\sqrt{x^2 + y^2})$
 d) $E = 3\sigma/(2\epsilon_0)$
 e) $E = \sqrt{5}[\sigma/(2\epsilon_0)]$
2. A hollow conducting sphere has an inner radius of $r_I = 0.80$ m and an outer radius of $r_O = 1.20$ m. The sphere carries a charge of $Q_S = -500$ nC. A separate point charge of $q = +300$ nC is located at the center of the sphere. What is the charge Q_O on the outer surface of the conducting sphere?

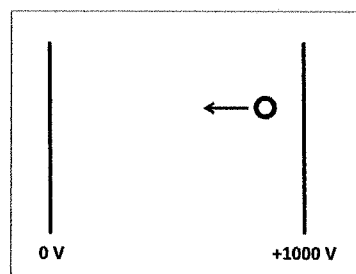
- a) $Q_O = -200$ nC
 b) $Q_O = \text{zero}$
 c) $Q_O = -300$ nC
 d) $Q_O = -500$ nC
 e) $Q_O = -800$ nC

$$-500 \text{ nC} + 300 \text{ nC} = -200 \text{ nC}$$

$$Q_O = Q_{\text{enclosed}}$$

3. A proton is moving through a potential difference of $V = +1000$ volts, as shown in the figure. How much kinetic energy K does the proton acquire? Note: magnitude of charge of proton = magnitude of charge of electron = 1.6×10^{-19} C.

- a) $K = +1.6 \times 10^{-16}$ J, independent of initial conditions.
 b) $K = -1.6 \times 10^{-16}$ J, independent of initial conditions.
 c) $K = +1.6 \times 10^{-16}$ J, only if the initial speed was zero.
 d) $K = \text{zero}$.
 e) $K = +1.6 \times 10^{-16}$ J, only if the initial potential energy was zero.

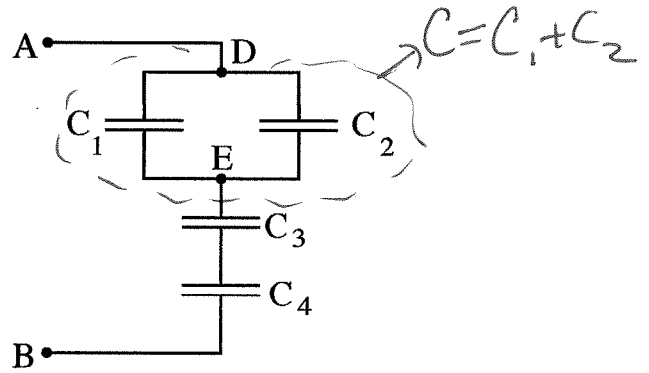


$$K_{\text{acquired}} = K_f - K_i = U_f - U_i = q[1000 \text{ V} - 0] = (1.6 \times 10^{-19} \text{ C})(1000 \text{ V})$$

$$= 1.6 \times 10^{-16} \text{ J}$$

4. Each capacitor in the figure has a capacitance of $C=10\ \mu\text{F}$. What is the equivalent capacitance C of this combination?

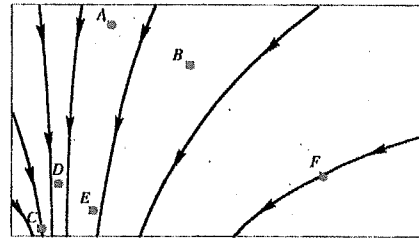
- a) $C = 10\ \mu\text{F}$
- b) $C = 50\ \mu\text{F}$
- c) $C = 25\ \mu\text{F}$
- ☒ d) $C = 4\ \mu\text{F}$
- e) $C = 2\ \mu\text{F}$



$$\frac{1}{C_{\text{eq}}} = \frac{1}{20} + \frac{1}{10} + \frac{1}{10} = \frac{1+2+2}{20} \Rightarrow C_{\text{eq}} = \frac{20}{5} = 4\ \mu\text{F}$$

5. In the figure are electric field lines; the charges that produced the electric field are not shown. Rank the magnitude of the electric field E for the points B, C, E, and F.

- a) $E_B > E_C > E_E > E_F$
- b) $E_F > E_E > E_C > E_B$
- c) $E_F \approx E_E > E_B > E_C$
- d) $E_F \approx E_E > E_C > E_B$
- ☒ e) $E_C > E_E > E_B > E_F$



6. An electric dipole is surrounded by a closed surface. Which statement is TRUE about the electric flux Φ through the surface?

- a) Φ is proportional to the dipole moment.
- ☒ b) $\Phi = \text{Zero}$.
- c) Φ is proportional to the dipole moment squared.
- d) Φ is a negative quantity.
- e) Φ cannot be determined without knowing the orientation of the dipole moment vector relative to the surface.

$$\Phi = \frac{Q_{\text{enclosed}}}{\epsilon_0} = \frac{+q - q}{\epsilon_0} = 0$$

7. Three point charges are located on the x -axis: $q_1 = -e$ at $x = 0$, $q_2 = +e$ at $x = a$, and $q_3 = +e$ at $x = 2a$. Calculate the potential energy U of the system of three charges.

- a) $U = +e^2/4\pi\epsilon_0 a$
 b) $U = -e^2/4\pi\epsilon_0 a$
 c) $U = +e^2/8\pi\epsilon_0 a$
 d) $U = -e^2/8\pi\epsilon_0 a$
 e) $U = -e^2/4\pi\epsilon_0 a^2$

$$U = \frac{-e^2}{4\pi\epsilon_0 a} - \frac{e^2}{8\pi\epsilon_0 a} + \frac{e^2}{4\pi\epsilon_0 a}$$

$$= \frac{-e^2}{8\pi\epsilon_0 a} (2 + 1 - 2) = \frac{-e^2}{8\pi\epsilon_0 a}$$

8. You combine three capacitors in *series*. Which of the following statements is TRUE about the net capacitance?

- a) The net capacitance is greater than the smallest individual capacitance. ~~F~~
 b) The net capacitance is equal to the sum of the capacitance of all of the three capacitors. ~~F~~
 c) The net capacitance is greater than the largest individual capacitance. ~~F~~
 d) The potential difference is the same across all of the capacitors. ~~F~~
 e) The charge is the same on all of the capacitors.

9. Two point charges of magnitude q and of opposite signs are separated by a distance d , forming an electric dipole. The charges are in a uniform electric field of magnitude E whose direction makes an angle $\theta = 30^\circ$ with respect to the dipole moment of the dipole. What is the magnitude of the torque τ on the electric dipole?

- a) $\tau = \text{zero}$
 b) $\tau = qdE$
 c) $\tau = qdE/2$
 d) $\tau = qdE\sqrt{3}/2$
 e) $\tau = qE/2$

$$\tau = |\vec{p} \times \vec{E}| = qdE \sin \theta$$

$$= qdE/2$$

10. A solid nonconducting sphere of radius R carries a uniform charge density $= \rho$ throughout its volume. At a radial distance $r_1 = R/4$ from the center, the electric field has magnitude E_1 . What is the magnitude of the electric field E_2 at a radial distance $r_2 = 2R$? Use Gauss's Law

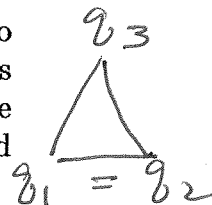
- a) $E_2 = E_1/2$
 b) $E_2 = 4E_1$
 c) $E_2 = \text{zero}$
 d) $E_2 = 2E_1$
 e) $E_2 = E_1$

$$E_1 = \frac{\rho}{\epsilon_0} \frac{4\pi (R/4)^3}{3} = \frac{\rho R^2}{3\epsilon_0}$$

$$E_1 = \frac{\rho (4\pi/3) (R/4)^3}{\epsilon_0 4\pi (R/4)^2} = \frac{\rho R}{3\epsilon_0}$$

$$E_2 = \frac{\rho (4\pi/3) (2R)^3}{\epsilon_0 (4\pi) (2R)^2} = \left(\frac{\rho R}{3\epsilon_0} \right) 4 \Rightarrow E_1 = E_2$$

11. Three point charges, which initially are infinitely far apart, are moved to the corners of an equilateral triangle with sides d . Two of the point charges are identical and have charge q . If zero net work is required to place the three charges at the corners of the triangle, what must the value of the third charge q_3 be?



- a) $q_3 = q$
 b) $q_3 = -q/2$
 c) $q_3 = -q$
 d) $q_3 = -2q$
 e) $q_3 = q/2$

$$W = 0 = \frac{kq^2}{d} + \frac{kqq_3}{d} + \frac{kqq_3}{d} = \frac{q^2}{d} + \frac{2qq_3}{d}$$

$$q_3 = \frac{-q^2}{2q} = -q/2$$

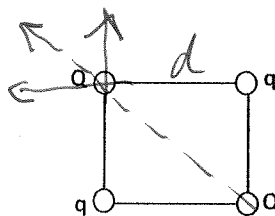
12. A $15 \mu\text{F}$ air-filled capacitor is connected to a $V_1 = 50 \text{ V}$ voltage source and becomes fully charged. The voltage source is then removed and a slab of dielectric that completely fills the space between the plates is inserted. The dielectric has a dielectric constant $\kappa = 5.0$. What is the potential difference V_2 across the plates of the capacitor after the slab has been inserted?

- a) $V_2 = 10 \text{ V}$
 b) $V_2 = 20 \text{ V}$
 c) $V_2 = 250 \text{ V}$
 d) $V_2 = 50 \text{ V}$
 e) $V_2 = 3 \text{ V}$

$Q_i = Q_f$
 $C_i V_i = C_f V_f$
 $(15 \mu\text{F})(50\text{V}) = 5(15 \mu\text{F}) V_f$

$\Rightarrow V_f = \frac{50\text{V}}{5} = 10\text{V}$

13. A charge of magnitude Q is placed at each of two opposite corners of a square. A charge of magnitude q is placed at each of the other two corners. If the net electric force F on Q is zero, what is Q/q ?



- a) $Q/q = -1$
 b) $Q/q = -1/\sqrt{2}$
 c) $Q/q = +1$
 d) $Q/q = -2\sqrt{2}$
 e) $Q/q = +2\sqrt{2}$

$$\sum F_Q^x = 0 = -\frac{kQq}{d^2} - \frac{kQ^2}{(\sqrt{2}d)^2} \frac{\sqrt{2}}{2} = 0$$

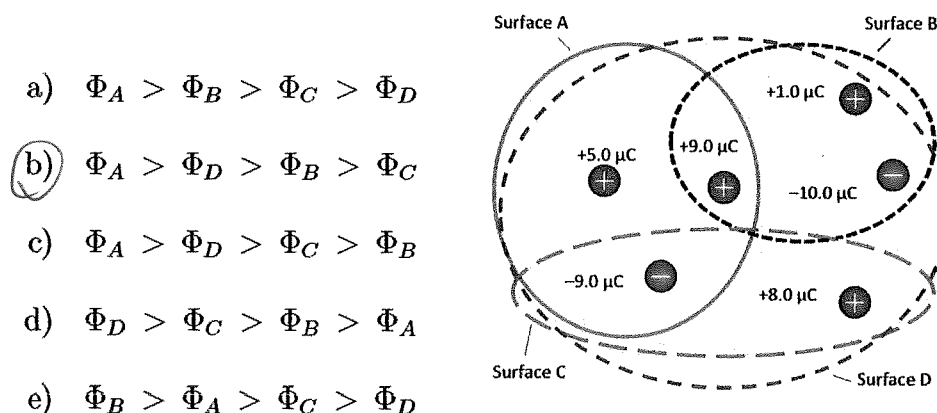
$$\sum F_Q^y = 0 = \frac{kQq}{d^2} + \frac{kQ^2}{(\sqrt{2}d)^2} \frac{\sqrt{2}}{2} = 0$$

$$F = \sqrt{F_x^2 + F_y^2} =$$

$$0 = \frac{q}{2} + \frac{Q}{2} \frac{\sqrt{2}}{2} \Rightarrow Q = -\frac{q}{\frac{\sqrt{2}}{2} \times \frac{\sqrt{2}}{2}} = -\frac{q}{1/2} = -2q$$

$$Q/q = -2$$

14. The figure shows six point charges that all lie in the same plane. Four Gaussian surfaces each enclose part of this plane, and the figure shows the intersection of each surface with the plane. Rank the flux Φ through the four surfaces in the figure.



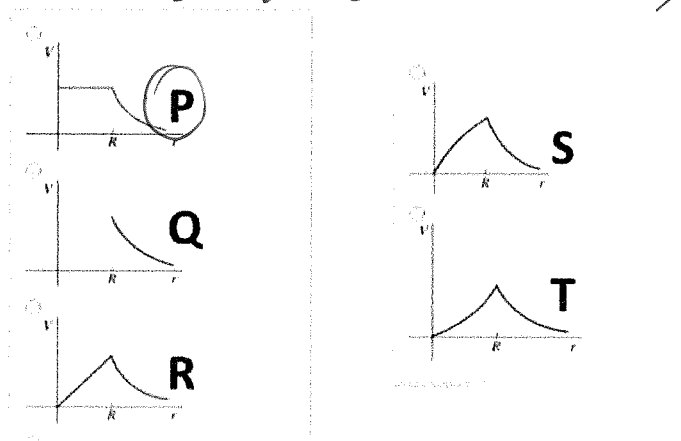
- a) $\Phi_A > \Phi_B > \Phi_C > \Phi_D$
 b) $\Phi_A > \Phi_D > \Phi_B > \Phi_C$
 c) $\Phi_A > \Phi_D > \Phi_C > \Phi_B$
 d) $\Phi_D > \Phi_C > \Phi_B > \Phi_A$
 e) $\Phi_B > \Phi_A > \Phi_C > \Phi_D$

$$\begin{aligned}\phi_D &= +5 + 9 \\ &\quad + 1 - 10 \\ &\quad - 9 + 8 \\ &= 4 \mu\text{C} / \epsilon_0\end{aligned}$$

$$\frac{+5 \mu\text{C}}{\epsilon_0} \phi_A = \frac{(5 + 9 - 9) \mu\text{C}}{\epsilon_0} \quad \phi_B = \frac{(1 + 9 - 10) \mu\text{C}}{\epsilon_0} = 0 \quad \phi_C = \frac{(-9 + 8) \mu\text{C}}{\epsilon_0} = \frac{-1 \mu\text{C}}{\epsilon_0}$$

15. A conducting sphere of radius R carries an excess positive charge and is very far from any other charges. Which one of the following graphs best illustrates the electrical potential (relative to infinity) produced by this sphere as a function of the distance r from the center of the sphere?

$$\begin{aligned}E_{\text{inside conductor}} &= 0 \Rightarrow V = \text{constant} & E(r > R) &\propto \frac{1}{r^2} \Rightarrow V \propto \frac{1}{r}\end{aligned}$$



- a) Graph Q
 b) Graph R
 c) Graph P
 d) Graph T
 e) Graph S