PHYSICS DEPARTMENT

PHY 2049, Spring 2013
Midterm 1
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Instructor(s): D. Acosta, R. Woodward

Name (print): __________________________ Signature: __________________________

On my honor, I have neither given nor received unauthorized aid on this examination.

YOUR TEST NUMBER IS THE 5-DIGIT NUMBER AT THE TOP OF EACH PAGE.

DIRECTIONS

(1) **Code your test number** on your answer sheet (use 78-80 for the 5-digit number). Code your name on your answer sheet. Darken circles completely (errors can occur if too light). Code your student number on your answer sheet.

(2) Print your name on this sheet and sign it also.

(3) Do all scratch work anywhere on this exam that you like. At the end of the test, this exam printout is to be turned in. No credit will be given without both answer sheet and printout with scratch work.

(4) Work the questions in any order. Incorrect answers are not taken into account in any way; you may guess at answers you don’t know.

(5) If you think that none of the answers is correct, please choose the answer given that is closest to your answer.

(6) **Blacken the circle of your intended answer completely, using a number 2 pencil.** Do not make any stray marks or the answer sheet may not read properly. Completely erase all incorrect answers, or take a new answer sheet.

(7) As an aid to the examiner (and yourself), in case of poorly marked answer sheets, please circle your selected answer on the examination sheet. Please remember, however, that in the case of a disagreement, the answers on the bubble sheet count, **NOT** what you circle here. Good luck!!

>>><<<<<<<<<<WHEN YOU FINISH <<<<<<<<<<<

Hand in the answer sheet separately.

<table>
<thead>
<tr>
<th>Constants:</th>
<th>$e = 1.6 \times 10^{-19}$ C</th>
<th>$m_p = 1.67 \times 10^{-27}$ kg</th>
<th>$m_e = 9.1 \times 10^{-31}$ kg</th>
<th>$\epsilon_0 = 8.85 \times 10^{-12} \text{C}^2/\text{N} \cdot \text{m}^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$k = 1/(4\pi \epsilon_0) = 9 \times 10^9 \text{N} \cdot \text{m}^2/\text{C}^2$</td>
<td>$\text{nano} = 10^{-9}$</td>
<td>$\text{micro} = 10^{-6}$</td>
<td>$\text{pico} = 10^{-12}$</td>
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1. A particle with charge $q_1 = -0.4e$ is at $x = 0$ and another particle with charge $q_2 = +3e$ is at $x = 0.63$ m. At what location along the $x$ axis and with what charge could a third particle be placed in order to bring the entire system into electrostatic equilibrium (all particles stationary)?

   (1) $x = -0.63$ m, $q = +3e$
   (2) $x = -0.37$ m, $q = +e$
   (3) $x = -0.21$ m, $q = +e$
   (4) $x = +1.26$ m, $q = -0.4e$
   (5) $x = +1.0$ m, $q = -e$

2. A capacitor is constructed by stacking three large conducting plates, each with surface area $A$, on top of each other. The middle plate is suspended a distance $d$ above the lower plate. The top plate is suspended a distance $2d$ above the middle plate. If the top plate is maintained at potential $V$, and the bottom plate is at zero potential, how much charge is there on the bottom surface of the top plate? Express your answer as a number times $\epsilon_0 AV/d$.

   (1) $3$  (2) $2$  (3) $1/2$  (4) $1/3$  (5) $1$

3. What is the $x$ component of the electric field at the center of the square array of charged particles with $q_1 = +2q$, $q_2 = +2q$, $q_3 = +2q$, and $q_4 = +q$? The side length $a = 10$ cm and $q = 2 \times 10^{-8}$ C.

   (1) $3600$ N/C
   (2) $-2550$ N/C
   (3) $-5100$ N/C
   (4) $1270$ N/C
   (5) $0$

4. Consider the capacitor formed by a conducting sphere of radius $R$, with the other surface at infinity. What is the capacitance of this system?

   (1) $4\pi \epsilon_0/R$
   (2) $4\pi \epsilon_0$
   (3) $2\pi \epsilon_0/R$
   (4) $4\pi \epsilon_0 R$
   (5) $2\pi \epsilon_0 R$
5. A glass rod forms a quarter circle of radius $R = 2.5$ cm with a charge of $q = +10^{-11}$ C distributed uniformly along it. What is the $x$ component of the electric field at the center of the arc (the origin of the axes shown)?

(1) $520$ N/C  
(2) $-144$ N/C  
(3) $-23$ N/C  
(4) $-92$ N/C  
(5) 0

6. A rod of charge per unit length $\lambda_1$ is surrounded by a thin, concentric cylinder of charge per unit length $\lambda_2$ and radius $R$ (see figure). What is the magnitude of the electric field at a radius $r > R$?

(1) $\frac{\lambda_1}{2\pi \varepsilon_0 r}$  
(2) 0  
(3) $\frac{\lambda_1 + \lambda_2}{2\pi \varepsilon_0 r}$  
(4) $\frac{\lambda_2}{2\pi \varepsilon_0 r}$  
(5) $\frac{\lambda_1 - \lambda_2}{2\pi \varepsilon_0 r}$

7. The figure gives the magnitude of the electric field inside and outside a solid sphere with a positive charge distributed uniformly throughout its volume. The scale of the vertical axis is set by $E_s = 5.0 \times 10^7$ N/C. What is the total charge of the sphere?

(1) $2.2 \mu$C  
(2) $110 \mu$C  
(3) $55 \mu$C  
(4) 0  
(5) $0.5 \mu$C

8. The electric potential is $V(x, y) = A \sin(kx) \cos(ky)$, where $A$ and $k$ are constants. What is the $y$ component of the electric field?

(1) $Ak \sin(kx) \sin(ky)$  
(2) $A/k \sin(kx) \cos(ky)$  
(3) $-Ak \sin(kx) \sin(ky)$  
(4) $A \cos(ky)$  
(5) $Ak \sin(ky)$

9. Two identical conducting spheres are separated by a fixed distance of $d = 30$ cm, which is much larger than the sphere radius. The sphere charges are initially $q_1 = +1.0$ nC and $q_2 = -4.0$ nC. They are then connected by a thin conducting wire and then disconnected. What is the magnitude of the electrostatic force in N between the spheres?

(1) $10^{-7}$  
(2) $2 \times 10^{-7}$  
(3) $5 \times 10^{-7}$  
(4) $3 \times 10^{-7}$  
(5) $4 \times 10^{-7}$

10. The electric field vector is $\vec{E}(x, y) = \hat{i}a + \hat{j}b$, where $a$ and $b$ are constants. What is the electric potential $V(x, y)$ for this field?

(1) $-ab$  
(2) $ax$  
(3) $-ax - by$  
(4) $-abxy$  
(5) $ax + by$

11. What is the total enclosed charge in the shown cube if the electric field is given by $\vec{E} = -3\hat{i} + 2y^2 \hat{j}$ and the cube has a side length of 2?

(1) $32 \varepsilon_0$  
(2) $\varepsilon_0$  
(3) $4 \varepsilon_0$  
(4) 0  
(5) $16 \varepsilon_0$
12. A conducting cylinder of radius 2 cm contains 4 pC/m of charge along its length. An electron is released from rest 5 cm from the central axis. What is its kinetic energy in electron volts when it hits the cylinder?

(1) 0.0719  (2) 0.0659  (3) 0.414  (4) It never hits  (5) 0.132

13. An electron is positioned 0.5 cm above a large, flat non-conducting sheet of charge of surface charge density \( \sigma = +2.0 \, \mu C/m^2 \). When released from rest, how long does it take the electron to reach the sheet? \( (m_e = 9.11 \times 10^{-31} \, \text{kg}, \) \( e = 1.6 \times 10^{-19} \, \text{C}) \).

(1) \( 3 \times 10^{-5} \) s  (2) \( 10^5 \) s  (3) \( 5 \times 10^{-19} \) s  (4) \( 2 \times 10^{16} \) s  (5) \( 7 \times 10^{-10} \) s

14. Four identical charges \( q \) are arranged in a square of side length \( d \). What is the electrostatic energy of this system in units of \( q^2/(4\pi\varepsilon_0 d) \)?

(1) 0.48  (2) 0.22  (3) 0.40  (4) 0.43  (5) 0.32

15. A cylinder of radius 1 cm contains a negative charge density whose magnitude grows linearly with radius from zero with slope 5 pC/m\(^4\). What is the direction and magnitude of the electric field 0.5 cm from the central axis?

(1) none, zero  (2) inward, \( 4.71 \times 10^{-6} \, \text{N/C} \)  (3) outward, \( 4.71 \times 10^{-6} \, \text{N/C} \)  (4) outward, \( 7.06 \times 10^{-6} \, \text{N/C} \)  (5) inward, \( 7.06 \times 10^{-6} \, \text{N/C} \)

16. An air-filled parallel-plate capacitor has a capacitance of \( 1 \, \mu F \) and has a potential difference of 100 V between the plates. If the gap between the plates is inserted with a dielectric material with dielectric constant \( \kappa = 2.5 \), how much additional energy is required to do this if the potential difference is maintained at 100 V?

(1) \( 5.0 \times 10^{-5} \) J  (2) \( 7.5 \times 10^{-3} \) J  (3) 0  (4) \( 2.0 \times 10^{-3} \) J  (5) \( 1.25 \times 10^{-2} \) J

17. What is the equivalent capacitance in \( \mu F \) of the circuit shown if each capacitor has a capacitance of \( 1 \, \mu F \)?

(1) \( 6/11 \)  (2) \( 11/6 \)  (3) \( 5/6 \)  (4) \( 6 \)  (5) \( 1/6 \)

18. In the shown figure, a potential difference of \( V = 12 \) V is applied across the arrangement of capacitors with capacitances of \( C_1 = C_2 = 4 \, \mu F \), and \( C_3 = 1 \, \mu F \). What is the charge \( q_3 \) on one of the plates of capacitor \( C_3 \)?

(1) \( 6 \, \mu C \)  (2) \( 48 \, \mu C \)  (3) \( 36 \, \mu C \)  (4) \( 12 \, \mu C \)  (5) \( 24 \, \mu C \)
19. Consider the electric dipole shown in the figure, where the distance \( r \) to point \( P \) is much larger than the dipole separation distance \( d \). If the distance \( r \) is doubled, what is the ratio of the magnitude of the electric field at the new location to that at the original position?

(1) 1/2  
(2) 1/4  
(3) 4  
(4) 1/8  
(5) 8

20. Consider a non-conducting horizontal plane with a charge density of \( \sigma = 3 \text{ nC/m}^2 \). A small ball of charge \( q = 2 \text{ nC} \) floats above the plane in the Earth's gravitational field. What is the ball's mass?

(1) \( 3.45 \times 10^{-8} \text{ kg} \)  
(2) \( 5.51 \times 10^{-8} \text{ kg} \)  
(3) \( 6.92 \times 10^{-8} \text{ kg} \)  
(4) \( 8.69 \times 10^{-7} \text{ kg} \)  
(5) \( 6.92 \times 10^{-4} \text{ kg} \)