Instructor(s): Profs. Korytov, Takano

PHYSICS DEPARTMENT
PHY 2049, Spring 2014
Midterm 1 February 10, 2014

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 76–80 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.

**Constants:**

\[ e = 1.6 \times 10^{-19} \text{C} \quad m_p = 1.67 \times 10^{-27} \text{kg} \quad m_e = 9.1 \times 10^{-31} \text{kg} \quad \epsilon_o = 8.85 \times 10^{-12} \text{C}^2/\text{N} \cdot \text{m}^2 \]

\[ k = 1/(4\pi \epsilon_o) = 9 \times 10^9 \text{N} \cdot \text{m}^2/\text{C}^2 \quad \text{nano} = 10^{-9} \quad \text{micro} = 10^{-6} \quad \text{pico} = 10^{-12} \]

Sphere: \[ A = 4\pi R^2 \quad V = \frac{4\pi}{3} R^3 \]

1. An electron and a proton are separated by a distance of \( d = 5.3 \times 10^{-11} \text{m} \). What is the magnitude of the acceleration of the electron immediately after both particles are released from rest?

   \( (1) \ 9.0 \times 10^{22} \text{m/s}^2 \quad (2) \ 8.2 \times 10^{-8} \text{m/s}^2 \quad (3) \ 4.8 \times 10^{12} \text{m/s}^2 \quad (4) \ 5.6 \times 10^{41} \text{m/s}^2 \quad (5) \ 1.0 \times 10^{13} \text{m/s}^2 \)

2. In the figure, \( q_1 = 300 \mu \text{C} \), \( q_2 = 400 \mu \text{C} \) and \( q_3 = 500 \mu \text{C} \), \( r_{12} = 9 \text{m} \), \( r_{13} = 12 \text{m} \).

   Compute the magnitude of the total force on \( q_3 \).

   \( (1) \ 16.5 \text{ N} \quad (2) \ 17.4 \text{ N} \quad (3) \ 5.6 \text{ N} \quad (4) \ 233 \text{ N} \quad (5) \ 281 \text{ N} \)

3. Two positive free point charges \( q \) and \( 4q \) are a distance \( L = 7.12 \text{ m} \) apart. A third charge \( Q \) is placed so that the entire system is in equilibrium. Find the ratio \( Q/q \).

   \( (1) \ -4/9 \quad (2) \ 4/9 \quad (3) \ 2/9 \quad (4) \ -2/9 \quad (5) \ -1/9 \)

4. Two electric dipoles, each having dipole moment \( p \) aligned along the direction of the \( x \)-axis, are separated by a large distance \( x \) (see figure). Which of the following equations approximate the magnitude of the force between these dipoles the best? **Hint:** For small values of \( \alpha \), you can use the following approximation: \[ \frac{1}{(1 + \alpha)^n} \approx 1 - n\alpha \]

   \( (1) \ \frac{3}{2\pi\epsilon_0} \cdot \frac{p^2}{x^4} \quad (2) \ \frac{1}{\pi\epsilon_0} \cdot \frac{p^2}{x^4} \quad (3) \ \frac{3}{4\pi\epsilon_0} \cdot \frac{p^2}{x^4} \quad (4) \ \frac{1}{2\pi\epsilon_0} \cdot \frac{p^2}{x^4} \quad (5) \ \frac{1}{4\pi\epsilon_0} \cdot \frac{p^2}{x^4} \)
5. A ball of mass \( m = 0.75 \) grams is suspended from a thread of negligible mass. The ball carries a charge \( q = +32 \times 10^{-6} \) C, and is placed in a uniform electric field of magnitude \( E \) which points to the left. If the angle \( \theta = 28^\circ \), what is the magnitude of the electric field? (Recall \( g = 9.80 \) m/s\(^2\).

\[
\begin{align*}
(1) & \quad 120 \text{ N/C} \\
(2) & \quad 60 \text{ N/C} \\
(3) & \quad 30 \text{ N/C} \\
(4) & \quad 20 \text{ N/C} \\
(5) & \quad 10 \text{ N/C}
\end{align*}
\]

6. Two large parallel metal plates are separated by a distance \( L \) and have a uniform electric field between and perpendicular to them. An electron is released from the negatively charged plate at the same time that a proton is released from the positively charged plate. Neglect the force of the particles on each other and find their distance from the positively charged plate when they pass each other. Assume that \( m_p \approx 2000m_e \).

\[
\begin{align*}
(1) & \quad 0.005L \\
(2) & \quad 0.001L \\
(3) & \quad 0.005L \\
(4) & \quad 0.01L \\
(5) & \quad 0.5L
\end{align*}
\]

7. Which of the four-charge configurations has the strongest electric field at its center? The plus symbol indicates a positive charge \(+q\), and the minus symbol indicates a negative charge \(-q\).

\[
\begin{align*}
(1) & \quad \text{Insufficient information} \\
(2) & \quad \text{Insufficient information} \\
(3) & \quad \text{Insufficient information} \\
(4) & \quad \text{Insufficient information} \\
(5) & \quad \text{Insufficient information}
\end{align*}
\]

8. Three infinite parallel planes are separated by distances \( d \) and \( 2d \) and carry charge densities \(+\sigma, -2\sigma, +3\sigma\), as shown in the figure. What is the strength of the electric field at point \( A \) in the middle between the second and third planes?

\[
\begin{align*}
(1) & \quad \frac{2\sigma}{\varepsilon_0} \\
(2) & \quad \frac{\sigma}{\varepsilon_0} \\
(3) & \quad \frac{\sigma}{2\varepsilon_0} \\
(4) & \quad \frac{3\sigma}{2\varepsilon_0} \\
(5) & \quad \frac{3\sigma}{\varepsilon_0}
\end{align*}
\]

9. A cube with edges of length 10 cm rests on the \( y = 0 \) plane, with one edge along the line \( x = 2\text{cm} \) and another edge along \( x = 12\text{cm} \), as shown in the figure. A nonuniform field (in N/C) pierces the cube and is described by \( \vec{E}(x) = A\hat{i} \) where \( A = 7.0 \times 10^6 \) N/(C·m). How much charge (in C) is inside the cube?

\[
\begin{align*}
(1) & \quad 6.2 \times 10^{-8} \\
(2) & \quad 7.4 \times 10^{-8} \\
(3) & \quad 8.7 \times 10^{-8} \\
(4) & \quad -6.2 \times 10^{-8} \\
(5) & \quad -8.7 \times 10^{-8}
\end{align*}
\]
10. A point charge of charge \(-Q\) is placed at the center of a solid spherical conducting shell of inner radius \(R\) and outer radius \(2R\). The shell is in static equilibrium and has a net charge \(+2Q\). What is the total charge on the outer surface (at \(r = 2R\)) of the shell?

(1) \(+Q\)  (2) \(-Q\)  (3) \(0\)  (4) \(-2Q\)  (5) \(+2Q\)

11. What is the magnitude of the electric field at distance \(r = 1.5R\) from the center of the shell in the previous problem?

(1) \(0\)  (2) \(\frac{Qk}{(1.5R)^2}\)  (3) \(\left| \frac{Qk}{(1.5R)^2} - \frac{2Qk}{(2R)^2} \right|\)  (4) \(\left| \frac{Qk}{(1.5R)^2} - \frac{2Qk}{(1.5R)^2} \right|\)  (5) \(\frac{2Qk}{(1.5R)^2}\)

12. A spherical ball (an insulator) of radius \(R\) has uniform volume charge density \(\rho\). At what radius or radii from the center of the sphere is the electric field strength reduced by a factor of 9 from the electric field strength at the surface of the ball?

(1) at both \(3R\) and \(R/9\)  (2) at both \(9R\) and \(R/3\)  (3) at both \(3R\) and \(R/3\)  (4) at both \(9R\) and \(R/9\)  (5) at \(3R\) only

13. An infinite plate has negative uniform charge density \(-\sigma\). What is the difference of potentials between points \(P\) and \(O\): \(V_P - V_O\)?

(1) \(\frac{\sigma}{2\epsilon_0} \cdot d\)  (2) \(-\frac{\sigma}{2\epsilon_0} \cdot d\)  (3) \(\frac{\sigma}{2\epsilon_0} \cdot \sqrt{2d}\)  (4) \(-\frac{\sigma}{\epsilon_0} \cdot \sqrt{2d}\)  (5) \(-\frac{\sigma}{\epsilon_0} \cdot d\)

14. Electric field potential is \(V(x, y, z) = x^3 + yz^2 + 1\), where \(V\) is in volts and \(x\), \(y\), and \(z\) are in meters. Find the magnitude of electric field strength at point \((x, y, z) = (1, 1, 1)\).

(1) 3.7 N/C  (2) 1.4 N/C  (3) 7.1 N/C  (4) 2.7 N/C  (5) 5.9 N/C

15. Two charged metal spheres are connected by a copper wire, as shown in the figure. Note that \(r_A = 2r_B\), where \(r_A\) and \(r_B\) are the radii of spheres \(A\) and \(B\), and the spheres are far apart. What is the ratio \(\sigma_A/\sigma_B\) of surface charge densities?

(1) \(\frac{1}{2}\)  (2) 2  (3) 4  (4) \(\frac{1}{4}\)  (5) 1

16. In the rectangle shown, the sides have lengths 5 cm and 15 cm, \(q_1 = -7.5\) C, and \(q_2 = +2.5\) C. How much work (in joules) is required to move a third charge \(q_3 = +2.5\) C from \(A\) to \(B\) along a diagonal of the rectangle?

(1) \(3.0 \times 10^{12}\)  (2) \(4.0 \times 10^{12}\)  (3) \(5.0 \times 10^{12}\)  (4) \(6.0 \times 10^{12}\)  (5) \(7.0 \times 10^{12}\)
17. In the figure shown, each capacitor is charged to a potential difference of 100 V. After switches $S_1$ and $S_2$ are closed, what is the final potential difference $V_b - V_a$ in volts between point $a$ and point $b$? Note that $C_1 = 1 \mu F$ and $C_2 = 3 \mu F$.

1. 50 V  
2. 33 V  
3. 25 V  
4. 10 V  
5. 5 V

18. Five capacitors, each of capacitance $C$, are connected as shown in the figure. What is the equivalent capacitance of the arrangement?

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

19. In the figure a potential difference of $V = 6V$ is applied across a capacitor arrangement with capacitances $C_1 = 1 \mu F$, $C_2 = 2 \mu F$, and $C_3 = 3 \mu F$. What is charge $Q$ on capacitor 1?

1. $3 \mu C$  
2. $1 \mu C$  
3. $6 \mu C$  
4. $2 \mu C$  
5. $4 \mu C$

20. A conducting sphere of radius $R$ carries charge $-Q$. What is the total energy stored in the electric field surrounding the sphere?

1. $\frac{Q^2}{8\pi\epsilon_0 R}$  
2. $\frac{Q^2}{4\pi\epsilon_0 R}$  
3. $\frac{Q^2}{2\pi\epsilon_0 R}$  
4. $\frac{Q^2}{\pi\epsilon_0 R}$  
5. $\frac{Q^2}{16\pi\epsilon_0 R}$

THE FOLLOWING QUESTIONS, NUMBERED IN THE ORDER OF THEIR APPEARANCE ON THE ABOVE LIST, HAVE BEEN FLAGGED AS CONTINUATION QUESTIONS: 11