USNA Physics Department

LCDR Shivok’s SP212

First Exam PRACTICE VERSION 2016

Chapters 21 → 24

Electric Charge, Quantized Charge, Conservation of Charge, Conductors and Insulators, Coulomb’s Law, Electric Fields and their effects, Millikan Experiment, Dipoles and how they are affected by external Electric Fields, Gauss’ Law, Flux, Electric Potential Energy, and Electric Potential/Voltage.

This is not an assignment! If you use these problems to help you determine the areas in which you are weak, I believe they will help you prepare for the First Examination. DO NOT confine your study to just these problems. This is a REVIEW PROBLEM exercise, NOT an all encompassing gouge!

Exam 1 Breakdown

<table>
<thead>
<tr>
<th></th>
<th>Takehome</th>
<th>Pts</th>
<th>Inclass</th>
<th>Pts</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH-21</td>
<td>3Q’s</td>
<td>7.5</td>
<td>2Q’s</td>
<td>12</td>
</tr>
<tr>
<td>CH-22</td>
<td>5Q’s</td>
<td>12.5</td>
<td>3Q’s</td>
<td>18</td>
</tr>
<tr>
<td>CH-23</td>
<td>4Q’s</td>
<td>10</td>
<td>2Q’s</td>
<td>12</td>
</tr>
<tr>
<td>CH-24</td>
<td>4Q’s</td>
<td>10</td>
<td>3Q’s</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>16 Q’s</td>
<td>40</td>
<td>10 Q’s</td>
<td>60</td>
</tr>
</tbody>
</table>
Chapter 21 (12 points)

1. (2 points) A particle of charge \( q_1 = 2.00 \times 10^{-6} \text{C} \) is fixed in place. A second particle of charge \( q_2 = 4.00 \times 10^{-15} \text{C} \) and mass \( m_2 = 3.00 \times 10^{-9} \text{kg} \) is released from rest at a distance of \( r = 0.120 \text{ m} \) from the first particle. **What is the magnitude of the acceleration of the second particle?**

A) 1.66 m/s\(^2\)
B) 3.66 m/s\(^2\)
C) 2.66 m/s\(^2\)
D) 0.66 m/s\(^2\)
E) None of the above

Show all work:

2. (2 points) The (excess) charge on individual small drops was reported to be the following:

<table>
<thead>
<tr>
<th>Drop</th>
<th>Charge q</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(-8.0 \times 10^{-19} \text{C})</td>
</tr>
<tr>
<td>2</td>
<td>(-4.8 \times 10^{-19} \text{C})</td>
</tr>
<tr>
<td>3</td>
<td>(-4.0 \times 10^{-19} \text{C})</td>
</tr>
<tr>
<td>4</td>
<td>(-9.6 \times 10^{-19} \text{C})</td>
</tr>
</tbody>
</table>

**Which of these values is impossible?**

A) Drop 1
B) Drop 2
C) Drop 3
D) Drop 4
E) Drops 2 & 4

Show all work / explain why:
3. **(1 point)** Identify the missing quantity (periodic table is on page A-15 of your book):

\[ ^{222}_{88} \text{Ra} \rightarrow ^{209}_{82} \text{Pb} + ? ? \]

A) Carbon-12  
B) Carbon-14  
C) Silicon  
D) 2 Nitrogen atoms  
E) None of the above

**Show all work:**

4. **(3 points)** In Fig. below, particle 3 with charge \( q_3 \) is to be moved along the axis between particle 1 (charge \( q_1 = -2e \)) and particle 2 (charge \( q_2 = +16e \)). **At what coordinate \( x \) is the magnitude of \( \text{F}_{3,\text{net}} \) of the net force on particle 3 least?**

![Diagram](a)

**Show all work:**

A) 0.33d m  
B) -3.3d m  
C) 1.33d m  
D) 0.66d m  
E) None of the above
5. (4 points) A $+5.0 \times 10^{-5}$ C point charge is located at the origin, a $-4.0 \times 10^{-5}$ C point charge is located at $(0,2.0)$ m and a $+3.0 \times 10^{-5}$ C point charge is located at $(1.0,0)$ m. What is the magnitude and direction of the net (total) electric force on the charge at the origin?

Show all work:
Chapter 22 (18 points)

6. (4 points) Figure below shows a rod of length $L = 6.00$ cm and uniformly distributed charge $Q = 4.0 \times 10^{-15}$ C. Setup the integral required to find the net electric field at point $p$, which is on the axis of the rod at distance $d=2.00$ cm from the left end. (DO NOT TRY TO SOLVE THE INTEGRAL, only setup!)

Show all work (Every step taken):
7. **(1 point)** An electron moves along an electric field line in the positive direction of an x axis. At coordinate $x_0$ it has speed $v_0 = 500 \text{ m/s}$. At a farther point $x$ it has speed $v = 400 \text{ m/s}$. If the field magnitude is $E = 250 \text{ N/C}$, what is the displacement $\Delta x = x - x_0$ between those two points and in what direction does the field $\vec{E}$ point?

<table>
<thead>
<tr>
<th>$\Delta x$</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) $1.0 \times 10^{-8} \text{ m}$</td>
<td>Left</td>
</tr>
<tr>
<td>B) $2.0 \times 10^{-9} \text{ m}$</td>
<td>Right</td>
</tr>
<tr>
<td>C) $1.0 \times 10^{-9} \text{ m}$</td>
<td>Left</td>
</tr>
<tr>
<td>D) $1.0 \times 10^{-9} \text{ m}$</td>
<td>Right</td>
</tr>
<tr>
<td>E) $2.0 \times 10^{-9} \text{ m}$</td>
<td>Left</td>
</tr>
</tbody>
</table>

Show all work:

8. **(1 point)** An electron moves along an electric field line in the positive direction of an x axis. At time $t = 0$ it has speed $v_0 = 500 \text{ m/s}$. At later time $t$ it has speed $v = 400 \text{ m/s}$. If the field magnitude is $E = 250 \text{ N/C}$, what is time $t$ and in what direction does the field $\vec{E}$ point?

A) $2.3 \times 10^{-12} \text{ s}$
B) $3.3 \times 10^{-12} \text{ s}$
C) $0.3 \times 10^{-12} \text{ s}$
D) $1.3 \times 10^{-12} \text{ s}$
E) None of the above

Show all work:
9. (3 points) Figure below shows a particle with charge $+9q$ at the origin of an $x$ axis and a particle with charge $-q$ at $x = L$. At what point is the net electric field due to these two charges zero?

![Diagram](image)

A) 0.5L m  
B) -5L m  
C) 1.5L m  
D) .75L m  
E) None of the above

Show all work:

10. (3 points) A uniform electric field $\vec{E} = [+E_x \hat{i} - 2E_x \hat{j} - 6000 \hat{k}] \frac{N}{C}$ interacts with dipole moment of an electric dipole. The torque on the dipole is $[2.80 \times 10^{-5} \hat{i} + 1.70 \times 10^{-5} \hat{j} - 2.5 \times 10^{-6} \hat{k}] N \cdot m$ and the dipole moment vector is $[2.00 \times 10^{-9} \hat{i} - 3.00 \times 10^{-9} \hat{j} + 2.00 \times 10^{-9} \hat{k}] C \cdot m$. What is the electric field vector X-component?

Show all work:
11. (6 points total) Consider the electric dipole shown in the below diagram.

![Diagram of an electric dipole with charges +Q and -Q at points P1 and P2 respectively.]

**a. (2 points)** The row in the table that shows the best direction of the electric field at points P1 and P2, respectively is... Show how you arrived at this answer on drawing above.

<table>
<thead>
<tr>
<th>Row</th>
<th>Direction of E at P1</th>
<th>Direction of E at P2</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>→</td>
<td>←</td>
</tr>
<tr>
<td>B</td>
<td>→</td>
<td>→</td>
</tr>
<tr>
<td>C</td>
<td>←</td>
<td>←</td>
</tr>
<tr>
<td>D</td>
<td>←</td>
<td>→</td>
</tr>
<tr>
<td>E</td>
<td>↓</td>
<td>↑</td>
</tr>
</tbody>
</table>

**b. (4 points)** If the separation between the charges is 2.0 \times 10^{-9} m and the above dipole of charge Q=4.0 \mu C is placed as is in an external E field of \( \vec{E} = 5.4 \times 10^4 \frac{N}{C} \hat{j} \), what would be the magnitude and direction of the torque on that dipole?

A. 8.6 \times 10^{-10} \hat{k} \text{ N} \cdot \text{m}
B. 1.1 \times 10^{-10} \hat{k} \text{ N} \cdot \text{m}
C. 4.3 \times 10^{-10} \hat{k} \text{ N} \cdot \text{m}
D. -1.1 \times 10^{-10} \hat{k} \text{ N} \cdot \text{m}
E. -4.3 \times 10^{-10} \hat{k} \text{ N} \cdot \text{m}

Show all work:
Chapter 23 (12 points)

12. (4 points) Figure below shows a conducting shell with inner radius $R_i = 2.00 \times 10^{-4}$ m, outer radius $R_o = 3.00 \times 10^{-4}$ m and charge $q = 2.0 \times 10^{-14}$ C. **What is the magnitude of the electric field at radial points** $r_1 = 1.0 \times 10^{-4}$ m (inside the hollow), $r_2 = 2.5 \times 10^{-4}$ m (inside the wall), $r_3 = R_o$ (on the outer surface), and $r_4 = 6.0 \times 10^{-4}$ m (outside the shell)?

Show all work:
13. **(2 points)** Space vehicles traveling through Earth's radiation belts can intercept a significant number of electrons. The resulting charge buildup can damage electronic components and disrupt operations. Suppose a spherical metal satellite 1.3 m in diameter accumulates 2.4 μC of charge in one orbital revolution. **Calculate the magnitude of the electric field just outside the surface of the satellite, due to the surface charge.**

A) $5.1 \times 10^4$ N/C  
B) $2.1 \times 10^4$ N/C  
C) $3.1 \times 10^4$ N/C  
D) $5.1 \times 10^4$ N·m²/C  
E) None of the above

**Show all work:**

14. **(3 points)** A charged particle is suspended at the center of two concentric spherical shells that are very thin and made of nonconducting material. Figure below (a) shows a cross section. Figure below (b) gives the net flux $\Phi$ through a Gaussian sphere centered on the particle, as a function of the radius $r$ of the sphere. The scale of the vertical axis is set by $\Phi_s = 9.5 \times 10^5$ N·m²/C. **What is the net charge of shell A?** 

Hint: you should probably find the charge of the central particle first.

![Diagram](image)

A) $-3.36 \times 10^6$ C  
B) $1.01 \times 10^{-5}$ C  
C) $3.36 \times 10^6$ C  
D) $-1.01 \times 10^{-5}$ C  
E) $2.02 \times 10^6$ C

**Show all work:**
15. (3 points) Essay Question:
   
   a. Using physics phenomenon, explain WHY the following curves are shaped the way they are. Be as specific as possible.

   ![Graph of Electric Field vs Radial Distance for Conducting Sphere and Non-conducting Sphere](image)

   Conducting Sphere and Non-conducting Sphere

   (Uniform Charge density)

   b. Using physics phenomenon, explain what type of sphere would create an electric field vs radial distance graph that looks like the following curve.

   ![Graph of Electric Field vs Radial Distance](image)

   Show all work:
Chapter 24 (18 points)

16. (3 points) Three point charges are initially infinitely far apart. When the charges are infinitely far apart, their electrostatic potential energy is defined to be zero. The particles are brought together to form the configuration shown in the diagram.

The total electrostatic potential energy of the configuration of charges shown is closest to

A. -0.40 J.
B. 0.16 J.
C. 0.32 J.
D. 0.21 J.
E. -0.16 J.

Show all work:
17. (2 points) Figure below shows two charged particles fixed in place, with $q_1 = +5.0 \, q$ and $q_2 = -2.0 \, q$ and $L = 7.0$ cm. Other than at an infinite distance, at what coordinates on the x axis is $V = 0$?

Show all work:
18. (4 points) Figure below shows a point $P$ on the central axis through a thin ring (through the center of curvature and perpendicular to the plane of the ring). The ring holds a uniformly distributed charge $Q = 5.00 \times 10^{-15}$ C and has radius $R = 3.00$ cm. Point $P$ is at distance $d = 25.0$ cm from the ring’s center. **What is the potential $V$ at $P$ due to the ring’s charge?**

A) 17.49 $\mu$V  
B) 17.49 pV  
C) 17.49 fV  
D) 17.49 mV  
E) None of the above

**Show all work:**
19. **(3 points)** Figure below depicts an electric dipole consisting of a proton \(q = 1.60 \times 10^{-19} \text{ C}\) and an electron \((-q = -1.60 \times 10^{-19} \text{ C}\) at separation \(d = 30.0 \text{ pm}\). **What is the electric potential \(V\) at points \(A\), \(B\), and \(C\), each a distance \(r = 80.0 \text{ nm}\) from the (center of) the dipole?**

![Diagram of an electric dipole](image)

<table>
<thead>
<tr>
<th></th>
<th>Point A</th>
<th>Point B</th>
<th>Point C</th>
</tr>
</thead>
<tbody>
<tr>
<td>A)</td>
<td>+6.74 \times 10^{-6} V</td>
<td>-6.74 \times 10^{-6} V</td>
<td>0 V</td>
</tr>
<tr>
<td>B)</td>
<td>0 V</td>
<td>+6.74 \times 10^{-6} V</td>
<td>-6.74 \times 10^{-6} V</td>
</tr>
<tr>
<td>C)</td>
<td>-6.74 \times 10^{-6} V</td>
<td>0 V</td>
<td>+6.74 \times 10^{-6} V</td>
</tr>
<tr>
<td>D)</td>
<td>+6.74 \times 10^{-6} V</td>
<td>+6.74 \times 10^{-6} V</td>
<td>+6.74 \times 10^{-6} V</td>
</tr>
<tr>
<td>E)</td>
<td>+6.74 \times 10^{-6} V</td>
<td>0 V</td>
<td>-6.74 \times 10^{-6} V</td>
</tr>
</tbody>
</table>

**Show all work:**

20. **(1 point)** An electron is moved from point \(A\) (where the electric potential is \(V_A = -5.00 \text{ V}\)) to point \(B\) (where the electric potential is \(V_B = 20.0 \text{ V}\)). If the electron is stationary initially and finally, **how much work is done by the agent moving the electron?**

A) \(4 \times 10^{-18} \text{ J}\)
B) \(2 \times 10^{-18} \text{ J}\)
C) \(-2 \times 10^{-18} \text{ J}\)
D) \(6 \times 10^{-18} \text{ J}\)
E) \(-4 \times 10^{-18} \text{ J}\)

**Show all work:**
21. (5 points) The thin plastic rod of length \( L = 10.0 \, cm \) in the figure below has a \textbf{nonuniform} linear charge density \( \lambda = cx \), where \( C = 49.9 \, \frac{pC}{m^2} \).

(a) (2.4 points) With \( V = 0 \) at infinity, setup the integral to find the electric potential at point \( P_2 \) on the \( y \) axis at \( y = D = 3.56 \, cm \).

Show all work (Don’t actually try to solve the integral, but show each of the other 6 steps) [Note: The step that is normally step 7, must now be BEFORE Step 5 since non-constant charge density]:

(b) (0.8 points) Now use the calculator and solve the integral first leaving the limits as variables (or zero) as appropriate; then using numbers. \textbf{Write down both the resultant equation, and the actual potential value.}

(c) (1.3 points) Find the electric field component \( E_y \) at \( P_2 \).

Show all work:

(d) (0.5 points) Why cannot the field component \( E_x \) at \( P_2 \) be found using the result of (a)?
Make sure you showed all your work for all problems! Do the idiot check on your math… Does $50 - 30 = 20$ or did you fat finger the calculator?