Physics 116b Test 1  September 21, 2004

Name: Test A  Seat: 

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1) Short Answer (17 points)(Show Your Work!)

a) If a 0.07 kg particle with charge 2.1 C is placed in an electric field, 
E=2.1 (N/C) and then released, how fast is the particle moving after a 
time t = 2.1 sec? (at t=0, the particle is at rest)

\[
v = at \quad a = \frac{F}{m} = \frac{qE}{m} \quad \text{in m/s}^2
\]

\[
v = \frac{qE}{m} = \frac{(2.1C)(2.1N/C)}{0.07kg} = 132.3 \text{ m/s}
\]

b) What is the Force/(unit length) on a infinitely long wire with linear 
charge density -1.4 mC/m if it is 0.9 meters away and parallel to an 
infinite long wire with linear charge density -1.4 mC/m?

Is this force attractive or repulsive with respect to, 
the other wire? (3) repulsive (like charges!)

\[
F = qE \quad \frac{F}{\lambda} = \frac{qE}{\lambda} = \lambda E_z
\]

\[
E_z = \frac{\lambda_2}{2\pi\epsilon_0} \quad F = \left(\frac{\lambda_1}{\lambda_2} - 2k\right)\frac{2(1.4 \times 10^{-3} \text{C/m})}{\sqrt{0.9 \text{m}}} = 3920 \text{N/m}
\]

c) A conducting spherical shell of inner radius R1 and outer radius R2 
has a charge of -2Q placed at its center and a net charge of -3Q 
placed on it (that is, the sum of the inner surface charge and the outer 
surface charge is -3Q). What is the surface charge density on the inner 
surface of the conducting shell at R1? Explain your reasoning.
(Hint: Remember what E is inside a conductor, and that E is a result of 
total enclosed charge.)

\[
\sigma \text{ at } R1 = \frac{+2Q}{4\pi(R1)^2}
\]

\[
\sigma = \frac{Q}{A} = \frac{+2Q}{4\pi(R1)^2}
\]
2) Capacitors (Show Your Work!)

a) Calculate the equivalent capacitance between points A and B assuming that all the capacitors are initially uncharged. Now, if a 10.0 V battery is used between points A and B to charge the capacitors up, what is the charge on the 3.0 pF capacitor after it is charged up?

\[ C_{AB} = 5.56 \, \text{pF} \]  \hspace{1cm} (5)
\[ Q \text{ (on 3pF)} = 6.66 \, \text{pC} \]  \hspace{1cm} (5)

\[ \frac{1}{C_{CD}} = \frac{1}{4 \, \text{pF}} + \frac{1}{4 \, \text{pF}} + \frac{1}{7 \, \text{pF}} \]
\[ C_{CD} = 1.556 \, \text{pF} \]

\[ C_{AB} = 4.00 \, \text{pF} + 1.556 \, \text{pF} \]

\[ V_{\text{across 3pF}} = \frac{15.56 \, \text{pC}}{7 \, \text{pF}} = 2.22 \, \text{V} \]

\[ Q_{\text{on 3pF}} = 3 \, \text{pF} \times 2.22 \, \text{V} = 6.66 \, \text{pC} \]

check:
\[ Q_{\text{on 4pF}} = 8.88 \, \text{pC} \]
\[ \frac{15.54 \, \text{pC}}{15.56 \, \text{pF}} \]

b) Now, the battery is removed! But the charge remains on the capacitors. If an uncharged 6.0 pF capacitor is now hooked up between points A and B, what is the charge on the 3.0 pF capacitor at electrostatic equilibrium?

like putting on a new battery

notice \( V_{3 \, \text{pF}} \approx 10 \, \text{V} \) so just need new \( V_{\text{AB}} \)

before \[ Q_{\text{total}} = (10 \, \text{V} \times 4 \, \text{pF}) + 10 \, \text{V} \times (1.556 \, \text{pF}) = 55.56 \, \text{pC} \]

\[ Q_{\text{before}} = Q_{\text{after}} \]

\[ Q_{\text{after}} = V_{\text{new}} \times (6.0 \, \text{pF} + 5.56 \, \text{pF}) \]
\[ V_{\text{new}} = \frac{55.56 \, \text{pC}}{11.556 \, \text{pF}} \]
\[ = 4.8 \, \text{V} \]

\[ \frac{Q_{\text{3pF after}}}{Q_{\text{3pF before}}} = \frac{V_{\text{AB}} \times Q_{\text{3pF after}}}{V_{\text{AB}} \times Q_{\text{3pF before}}} \]
\[ Q_{\text{3pF after}} = 6.66 \, \text{pC} \times \left(\frac{4.8 \, \text{V}}{10.0 \, \text{V}}\right) = 3.2 \, \text{pC} \]
3) Force and Potential (20 points Show Your Work!)

3 charged, conducting spheres are arrayed at the corner of an equilateral triangle as shown below:

The charge on each is:
Q1 = -2.0 nC
Q2 = 4.0 nC
Q3 = 3.0 nC

For 1 nC:
\[ |E| = \frac{k Q}{r^2} \]
\[ = \frac{9 \times 10^9 \text{ Nm}^2 \text{C}^{-2}}{(1.15 \text{ m})^2} \]
\[ = 9.13 \text{ N/C} \]

What is the Electric Field at point P at the center of the triangle due to the three charges?
\[ E_x = -2 \times 3.6 \text{ N/C} \]
\[ E_y = 29.1 \text{ N/C} \]

What is the Electric potential at a point P? How much work would have to be done to bring in a charge of 3.0 nC from infinity to point P?
\[ V = \frac{K Q}{r} \]
\[ V_{at \ P} = 39.13 \text{ V} \]
\[ \text{Work} = 1.17 \times 10^{-7} \text{ J} \]
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Name: Test B  Seat: _____

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1) Short Answer (17 points) (Show Your Work!)

a) If a 0.02 kg particle with charge 2.4 C is placed in an electric field, E=2.6 (N/C) and then released, how fast is the particle moving after a time t = 1.9 sec? (at t=0, the particle is at rest)

\[ v = \frac{2.4 \times 2.6 \times 1.9}{0.02} \text{ m/s} \]

For all the work

b) What is the Force/(unit length) on a infinitely long wire with linear charge density +1.2 mC/m if it is 0.5 meters away and parallel to an infinitely long wire with linear charge density -1.2 mC/m?

Is this force attractive or repulsive with respect to the other wire? (3) Opposite a attract

\[ F = \frac{1.2 \times 10^{-3} \text{ C/m}^2}{0.5 \text{ m}} \times 9 \times 10^9 \text{ N/m}^2 \]

(5)

\[ F/\text{length} = 518.4 \text{ N/m} \]

c) A conducting spherical shell of inner radius R1 and outer radius R2 has a charge of +2Q placed at its center and a net charge of -3Q placed on it (that is, the sum of the inner surface charge and the outer surface charge is -3Q). What is the surface charge density on the inner surface of the conducting shell at R1? Explain your reasoning.

(Hint: Remember what E is inside a conductor, and that E is a result of total enclosed charge.)

\[ \sigma \text{ at } R1 = \frac{-2Q}{4 \pi (R1)^2} \]
2) Capacitors (Show Your Work!)

a) Calculate the equivalent capacitance between points A and B assuming that all the capacitors are initially uncharged. Now, if a 5.0 V battery is used between points A and B to charge the capacitors up, what is the charge on the 3.0 pF capacitor after it is charged up?

\[
C_{AB} = 2.77 \text{ pF} \quad (5)
\]
\[
Q (\text{on 3pF}) = 4.62 \text{ pC} \quad (5)
\]

\[
\frac{13.85 \text{ pC}}{9 \text{ pF}} = 1.54 \text{ V}
\]

\[
\frac{9 \text{ pF}}{2.77 \text{ pF}, Q_{AB} = 5 \text{ V} (2.77 \text{ pF})} = 13.85 \text{ pC} = Q_{\text{on 9 pF}}
\]

b) Now, the battery is removed, but the charge remains on the capacitors. If an uncharged 5.0 pF capacitor is now hooked up between points A and B, what is the charge on the 3.0 pF capacitor at electrostatic equilibrium?

\[
Q_{\text{after}} = Q_{\text{before}} = 27.7 \text{ pC}
\]

but now

\[
\frac{Q_{\text{after}}}{7.77 \text{ pF}} = \frac{13.85 \text{ pC}}{7.77 \text{ pF}} = 1.78 \text{ V}
\]

\[
\text{note } Q_{3\text{pF}} < V_{AB} \quad 4.62 \text{ pF} \cdot \frac{1.78 \text{ V}}{5 \text{ V}} = 1.64 \text{ pC}
\]
3) Force and Potential (20 points Show Your Work!)

3 charged, conducting spheres are arrayed at the corner of an equilateral triangle as shown below:

The charge on each is:
Q1 = -5.0 nC
Q2 = -2.0 nC
Q3 = 3.0 nC

The Electric Field at point P at the center of the triangle due to the three charges is:

\[ E_1 = 6.746 \frac{N}{C} \left( -i + j \right) \]
\[ E_2 = 6.746 \frac{N}{C} \left( -\cos 30^\circ i - \sin 30^\circ j \right) \]
\[ E_3 = 6.746 \frac{N}{C} \left( -\cos 30^\circ i + \sin 30^\circ j \right) \]

The total electric field is:
\[ 6.746 \frac{N}{C} \left( -1.73 - 2.6i + 5 - 1 + 1.5j \right) \]

What is the Electric potential at a point P? How much work would have to be done to bring in a charge of +5.0 nC from infinity to point P?

\[ V = \frac{(9 \times 10^{-9} \frac{Nm^2}{C^2})}{1.155m} \left( -5nC + 3nC - 2nC \right) \]

\[ V = -31.2 \frac{N}{m} \]

\[ U@\infty = 0 \]
\[ U@P = qV = -156 \text{J} \]

U is lower, E did the work
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1) Short Answer (17 points)(Show Your Work!)

a) If a 0.04 kg particle with charge 2.6 C is placed in an electric field, E=2.7 (N/C) and then released, how fast is the particle moving after a time t = 2.0 sec? (at t=0, the particle is at rest)

\[ v = \frac{2.6 \cdot 2.7 \cdot 2.0}{0.04} = 351 \text{ m/s} \]  

b) What is the Force/unit length) on a infinitely long wire with linear charge density +1.2 mC/m if it is 0.3 meters away and parallel to an infinitely long wire with linear charge density +1.2 mC/m?

Is this force attractive or repulsive with respect to the other wire? (3) [likes repel]

\[ F/\text{length} = 86400 \text{ N/m} \]

\[ \frac{F}{l} = \frac{(1.2 \times 10^{-3} \text{ C/m})^2 (9 \times 10^9 \text{ N C}^2)}{(0.3 \text{ m})} \]

\[ = 86400 \text{ N/m} \]

c) A conducting spherical shell of inner radius \( R_1 \) and outer radius \( R_2 \)

has a charge of +2Q placed at its center and a net charge of +3Q placed on it (that is, the sum of the inner surface charge and the outer surface charge is +3Q). What is the surface charge density on the inner surface of the conducting shell at \( R_1 \)? Explain your reasoning.

(Hint: Remember what E is inside a conductor, and that E is a result of total enclosed charge.)

\[ \sigma \text{ at } R_1 = \frac{2Q}{4\pi R_1^2} \]

\[ +3Q \text{ net charge on the conductor} \]
2) Capacitors (Show Your Work!)

a) Calculate the equivalent capacitance between points A and B assuming that all the capacitors are initially uncharged. Now, if a 20.0 V battery is used between points A and B to charge the capacitors up, what is the charge on the 3.0 pF capacitor after it is charged up?

\[
C_{AB} = 3.39 \text{ pF} \quad (5)
\]

\[
Q \text{ (on 3pF)} = 19.4 \text{ pC} \quad (5)
\]

\[
V_{CD} = \frac{Q_{CD}}{C_{CD}} = \frac{67.8 \text{ pC}}{10.5 \text{ pF}} = 6.46 \text{ V}
\]

\[
= V \text{ across 3pF}
\]

\[
Q_{3 \text{pF}} = 6.46 \text{ V} \cdot 3 \text{ pF} = 19.4 \text{ pC}
\]

\[
Q_{AB} = 67.8 \text{ pC} = Q_{CD}
\]

b) Now, the battery is removed, but the charge remains on the capacitors. If an uncharged 6.0 pF capacitor is now hooked up between points A and B, what is the charge on the 3.0 pF capacitor at electrostatic equilibrium?

\[
Q_{\text{Before}} = Q_{\text{After}}
\]

\[
A \rightarrow \frac{10.5 \text{ pF}}{5.0 \text{ pF}} \rightarrow A
\]

\[
V_{AB} = \frac{67.8 \text{ pC}}{9.39 \text{ pF}} = 7.22 \text{ V}
\]

\[
V_{AB} = Q_{3 \text{pF}} \text{ (see above!)}
\]

\[
(19.4 \text{ pC}) \left( \frac{7.22 \text{ V}}{20 \text{ V}} \right) = 7 \text{ pC}
\]
3) Force and Potential (20 points Show Your Work!)
3 charged, conducting spheres are arrayed at the corner of an equilateral triangle as shown below:

The charge on each is:
Q1 = -4.0 nC
Q2 = -2.0 nC
Q3 = 5.0 nC

What is the Electric Field at point P at the center of the triangle due to the three charges?

\[ E_1 = 6.746 \text{ N/C}(4) \left( \hat{i} + 0 \right) \]
\[ E_2 = 6.746 \text{ N/C}(2) \left( \sin 30^{\circ} \hat{i} + \cos 30^{\circ} \hat{j} \right) \]
\[ E_3 = 6.746 \text{ N/C}(5) \left( \sin 30^{\circ} \hat{i} - \cos 30^{\circ} \hat{j} \right) \]

\[ 6.746 \text{ N/C} \left[ 4 + 1 - 2.5 \hat{i} + (0 + 1.73 + 4.33) \hat{j} \right] \]

What is the Electric potential at a point P? How much work would have to be done to bring in a charge of 6.0 nC from infinity to point P?

\[ V = \left( 9 \times 10^9 \text{ Nm}^2/\text{C}^2 \right) \left( -4 \text{ nC} - 2 \text{ nC} + 5 \text{ nC} \right) \]

\[ 1.155 \text{ V} \]

\[ V \propto = 0 \]
\[ V_{@ P} = (6 \times 10^{-9} \text{ C}) \left( -7.8 \text{ Nm/C} \right) = -46.8 \text{ nJ} \]

\( DU \) negative  \( E \) did the work!
Physics 116b Test 1   September 21, 2004

Name: Test D   Seat: 

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1) Short Answer (17 points)(Show Your Work!)

a) If a 0.03 kg particle with charge 2.5 C is placed in an electric field, E=2.5 (N/C) and then released, how fast is the particle moving after a time t = 1.7 sec? (at t=0, the particle is at rest)

\[ v = \frac{(2.5 \text{ C})(2.5 \text{ m}^2/\text{C})(1.7 \text{ s})}{0.03 \text{ kg}} = 354 \text{ m/s} \]  

b) What is the Force/(unit length) on a infinitely long wire with linear charge density +1.5 mC/m if it is 0.6 meters away and parallel to an infinitely long wire with linear charge density -1.5 mC/m? Is this force attractive or repulsive with respect to the other wire?(3)

\[ F/\text{length} = \frac{G \times 10^{-9} \text{ N} \text{ m}^2/\text{C}^2}{(0.6 \text{ m})} \left( 1.5 \times 10^{-2} \text{ C} \right) \left( 2 \right) = 6.7494 \text{ N/m} \]  

c) A conducting spherical shell of inner radius R1 and outer radius R2 has a charge of -2Q placed at its center and a net charge of +3Q placed on it (that is, the sum of the inner surface charge and the outer surface charge is +3Q). What is the surface charge density on the inner surface of the conducting shell at R1? Explain your reasoning. (Hint: Remember what E is inside a conductor, and that E is a result of total enclosed charge.)

\[ \sigma \text{ at R}_1 = \frac{+2Q}{4\pi(R1)^2} \]
2) Capacitors (Show Your Work!)

a) Calculate the equivalent capacitance between points A and B assuming that all the capacitors are initially uncharged. Now, if a 15.0 V battery is used between points A and B to charge the capacitors up, what is the charge on the 3.0 pF capacitor after it is charged up?

\[
C_{AB} = 2.48 \text{ pF} \quad (5)
\]
\[
Q (on \ 3\text{pF}) = 6.18 \text{ pC} \quad (5)
\]

\[
\frac{1}{4} + \frac{1}{x} = \frac{1}{2.54 \text{ pF}} = \frac{1}{2 \text{FF}F}
\]

\[
C_{CD} = 6.54 \text{ pF}
\]

\[
\frac{1}{x} = \frac{1}{\text{4FF}F} + \frac{1}{6.54 \text{ pF}} = 2.48 \text{ pF} \quad Q_{AB} = 15.0V (2.48 \text{ pF}) = 37.2 \text{ pC} = Q_{CD} \quad V_{CD} = \frac{37.2 \text{ pC}}{6.54 \text{ pF}} = 5.69 \text{ V}
\]

b) Now, the battery is removed, but the charge remains on the capacitors. If an uncharged 2.0 pF capacitor is now hooked up between points A and B, what is the charge on the 3.0 pF capacitor at electrostatic equilibrium?

\[
Q (on \ 3\text{.0pF}) = 3.42 \text{ pC} \quad (5)
\]

\[
V_{AB} = \frac{37.2 \text{ pC}}{4.48 \text{ pF}} = 8.30 \text{ V}
\]

notice above \( Q_{3\text{FF}F} \approx 15 \text{0V}! \)

so \( Q_{After} = Q_{3\text{FF}F} \frac{V_{After}}{V_{Before}} \)

\[
= 6.18 \text{ pC} \left( \frac{8.30 \text{ V}}{15.0 \text{ V}} \right) = 3.42 \text{ pC}
\]
3) Force and Potential (20 points Show Your Work!)

3 charged, conducting spheres are arrayed at the corner of an equilateral triangle as shown below:

The charge on each is:
- Q1 = -4.0 nC
- Q2 = -1.0 nC
- Q3 = 3.0 nC

What is the Electric Field at point P at the center of the triangle due to the three charges?

\[
\begin{align*}
E_1 &= 6.746 \text{N/C} \left(4 \left(- \cos 30^\circ \hat{\mathbf{E}} + \sin 30^\circ \hat{\mathbf{J}}\right) \right) \\
E_2 &= 6.746 \text{N/C} \left(1 \left(\cos 30^\circ \hat{\mathbf{E}} + \sin 30^\circ \hat{\mathbf{J}}\right) \right) \\
E_3 &= 6.746 \text{N/C} \left(3 \left(0 \hat{\mathbf{E}} + \hat{\mathbf{J}}\right) \right)
\end{align*}
\]

\[
E_{\text{for 1 nC}} = \frac{6.746 \text{N}}{\text{C}}
\]

What is the Electric potential at a point P? How much work would have to be done to bring in a charge of -3.0 nC from infinity to point P?

\[
V = \left(9 \times 10^9 \frac{\text{C}^2}{\text{N} \cdot \text{m}^2}\right) \left(-4 \text{nC} - 1 \text{nC} + 3 \text{nC}\right) \frac{1}{1.155 \text{m}}
\]

\[
V = -15.58 \frac{\text{Nm}}{\text{C}}
\]

\[
u_{\infty} = 0
\]

\[
u_{P} = \frac{1}{\text{C}} \left(-3 \text{nC}\right) \left(-15.6 \frac{\text{Nm}}{\text{C}}\right) = 46.75 \text{nJ}
\]

took energy to bring it to P