Physics 116b Test 1 September 21, 2004

Name: Test A Seat:______

This is a 50 minute, closed book examination. Put answers in the boxes provided (if any). If numerical answers are needed, you must include units. Any work needed to justify the answer must be shown in the space provided, or as indicated on a separate piece of paper or elsewhere on the test. **A correct answer without the necessary justifying work may not receive any credit**. You may tear the formula sheet off the back of the exam.

Total points for each problem will appear in the table below and in ( ) beside each problem number. Do what is easiest first. AVOID glancing at anyone else's paper during the exam. No means of communication between other students or outside parties is allowed. **The honor code is in effect.**

You must do all the problems on this test.

Problem	Description	Max Score	Score
1	Short Answer	17	
2	Capacitors	15	
3	E & V	20	
Total		52	

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)

$v = at \quad a = \frac{F}{m} = \frac{qE}{m} \quad / \quad kg\frac{m}{s^2}$

v = 132.3 m/s	(5)

$v = \frac{qE}{m}t = \frac{(2.1C)(2.1N/C)}{0.07kg} 2.1s = 132.3 m/s$

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 infinitely 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/length = 39200 N/m	(5)

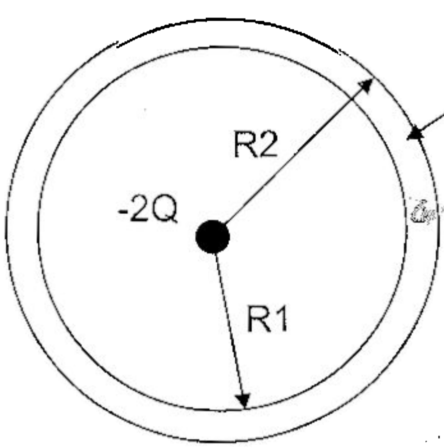
$F = qE \quad \frac{F}{\ell} = \frac{q}{\ell}E = \lambda_1 E_2$

$E_2 = \left(\frac{\lambda_2}{2\pi\varepsilon_0 y}\right) \quad \frac{F}{\ell} = \left(\frac{\lambda_1\lambda_2}{y}2k\right) = \frac{2(1.4\times10^{-3}C/m)^2(9\times10^9 N\frac{m^2}{C^2})}{(0.9m)} = 39200\frac{N}{m}$

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.)

σ at R1 = $\frac{+2Q}{4\pi(R1)^2}$	(4)

-3Q net charge on the conductor



$E = 0$ inside

$\frac{q_{enc}}{\varepsilon_0} = EA = 0(A)$

$q_{enc} = -2Q + Q_{inner\ surface}$

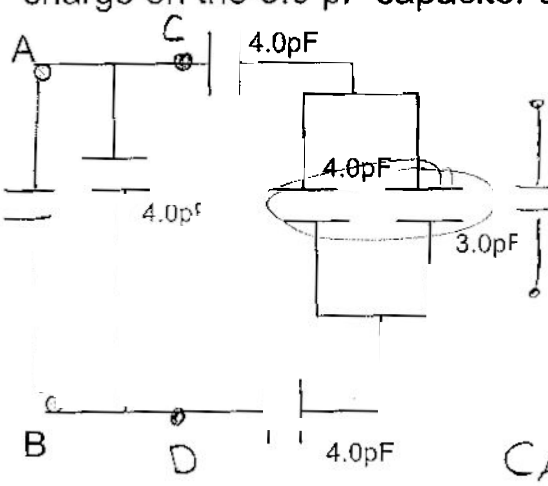
$Q_{inner surface} = +2Q$

$\sigma = \frac{Q}{A} = \frac{+2Q}{4\pi(R1)^2}$

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 pF	(5)
Q (on 3pF) = 6.66 pC	(5)



$\frac{1}{C_{CD}} = \frac{1}{4pf} + \frac{1}{4pf} + \frac{1}{7pf}$

$C_{CD} = 1.556pF$

$C_{AB} = 4.00pf + 1.556pf$

$V_{across}\ 3pf = \frac{15.56pC}{7pF} = 2.22V$

$Q_{on}\ 3pf = 3pF(2.22V) = 6.66pC$

check
$Q_{on}\ 4pF = 8.88pC$
15.54 pC ok!

10V across AB means
10V across C_{AB} & 10V across C_{CD}
so Q_{CD} is same as Q_{7pf} replacement $= 10V(1.556pF) = 15.56pC$

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 (on 3.0pF) = 3.2pC	(5)

like putting on a new battery

notice $V_{3pf} \propto 10V$ so just need new V_{ab}

Before $Q_{tot} = 10V(4pf) + 10V(1.556pf) = 55.56pF$

$= Q_{After}$

$Q_{After} = V_{new}(6.0pF + 5.556pF)$ in parallel

$V_{new} = \frac{55.56pC}{11.556pF} = 4.8V$

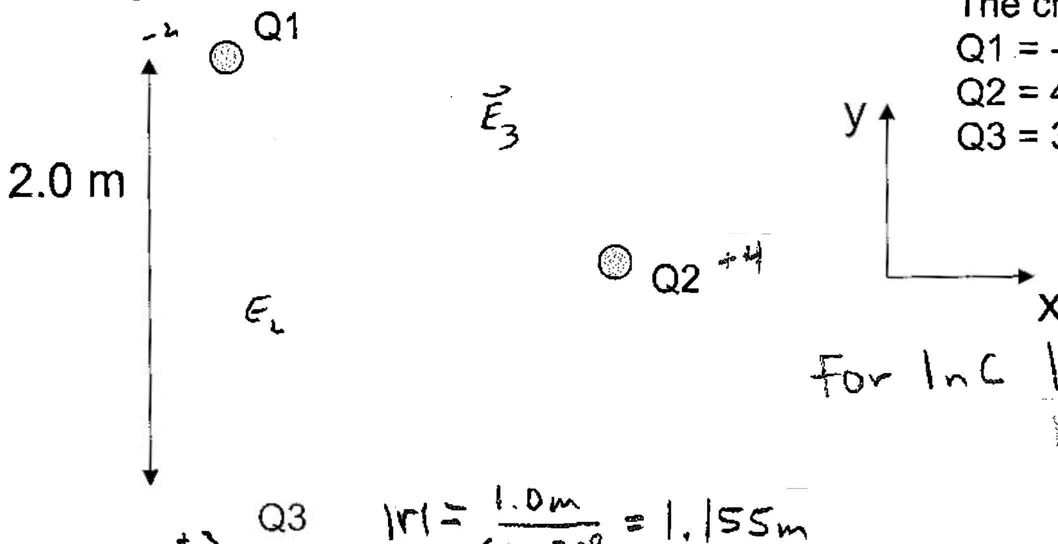
$\frac{Q^{After}_{3pf}}{Q^{before}_{3pf}} = \frac{V^{After}_{AB}}{V^{Before}_{AB}}$

$Q^{After}_{3pf} = 6.66pC\left(\frac{4.8V}{10.0V}\right) = 3.2pC$

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



$|r| = \frac{1.0\,m}{\cos 30^\circ} = 1.155\,m$

For 1nC $|E| = \frac{K\,1nC}{(1.155m)^2} = \frac{9\times10^9 N m^2/C^2 \cdot 1nC}{(1.155m)^2}$
$= (6.747\ N/C)$

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

← already took care of sign!

$1 = (6.747\tfrac{N}{C})(-2.0)[\sin 30^\circ \hat{i} + \cos 30^\circ \hat{j}]$

$2 = (6.747\tfrac{N}{C})(4.0)[\ -\hat{i} + 0\ ]$

$3 = (6.747\tfrac{N}{C})(3.0)[\sin 30^\circ \hat{i} + \cos 30^\circ \hat{j}]$

$6.747\tfrac{N}{C}[(-1 - 4 + 1.5)\hat{i}\ (+1.73 + 2.59)\hat{j}] = -23.6\tfrac{N}{C}\hat{i} + 29.1\tfrac{N}{C}$

Ex= $-23.6\ \frac{N}{C}$	(5)
Ey= $29.1\ \frac{N}{C}$	(5)

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?

$V = \frac{K(-2.0nC)}{1.15m} + \frac{k(4.0nC)}{1.15m} + \frac{k(3.0nC)}{1.15m}$

$= \frac{9\times10^9\ N\frac{m^2}{C^2}}{1.15m}(5\times10^{-9}C) = 39.13\ Nm/C$ ✓

V at P= 39.13 V	(5)
Work = 1.17×10^{-7} J	(5)

@ ∞, V=0 @ P, $U = (3\times10^{-9}C)(39.13\ Nm/C)$
$= 1.17\times10^{-7}$ J

U went up
took work to move it there

Physics 116b Test 1 September 21, 2004

Name: Test B____________ Seat:______

This is a 50 minute, closed book examination. Put answers in the boxes provided (if any). If numerical answers are needed, you must include units. Any work needed to justify the answer must be shown in the space provided, or as indicated on a separate piece of paper or elsewhere on the test. **A correct answer without the necessary justifying work may not receive any credit**. You may tear the formula sheet off the back of the exam.

Total points for each problem will appear in the table below and in ( ) beside each problem number. Do what is easiest first. AVOID glancing at anyone else's paper during the exam. No means of communication between other students or outside parties is allowed. **The honor code is in effect.**

You must do all the problems on this test.

Problem	Description	Max Score	Score
1	Short Answer	17	
2	Capacitors	15	
3	E & V	20	
Total		52	

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)

See test a For all the work

$v = \frac{(2.4C)(2.6\frac{N}{C})}{0.02kg}(1.9s)$

v = 592.8 m/S (5)

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) opposites attract

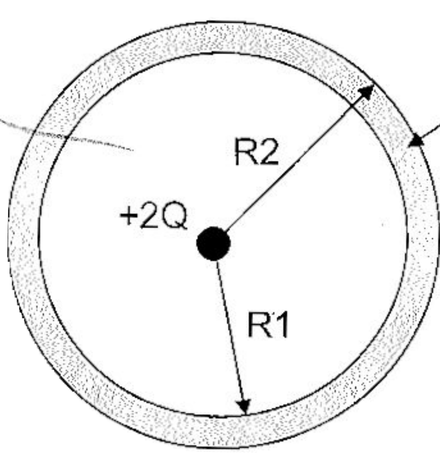
F/length = 51840 N/m (5)

$\frac{F}{l} = \frac{(1.2\times10^{-3}\ C/m)^2\,(9\times10^9\ N\frac{m^2}{C^2})}{(0.5m)} \times 2$

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.)

σ at R1 = $\frac{-2Q}{4\pi(R1)^2}$ (4)

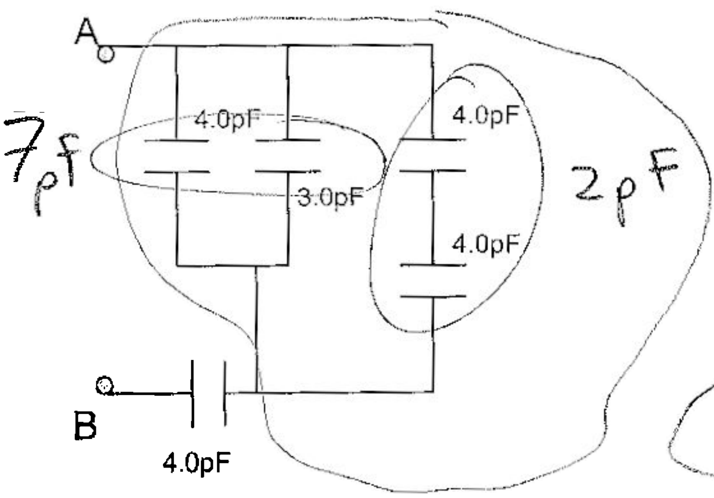
-3Q net charge on the conductor



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 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?

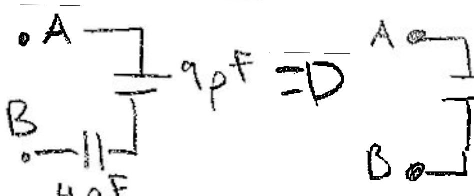
C_{AB}= 2.77pF	(5)
Q (on 3pF) =4.62pF	(5)



9pF

$V_{across\ 9pf} = \frac{13.85pC}{9pf} = 1.54V$

$= V_{across\ 3pf}$ $\quad Q_{3pf} = 1.54V(3.00pf) = 4.62pC$



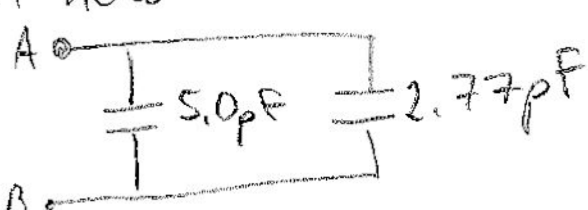
$2.77pF,\ Q_{AB} = 5V(2.77pF) = 13.85pC = Q_{on\ 9pF}$

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 (on 3.0pF) = 1.64pF	(5)

$Q_{After} = Q_{befor} = 27.7pC$

but now



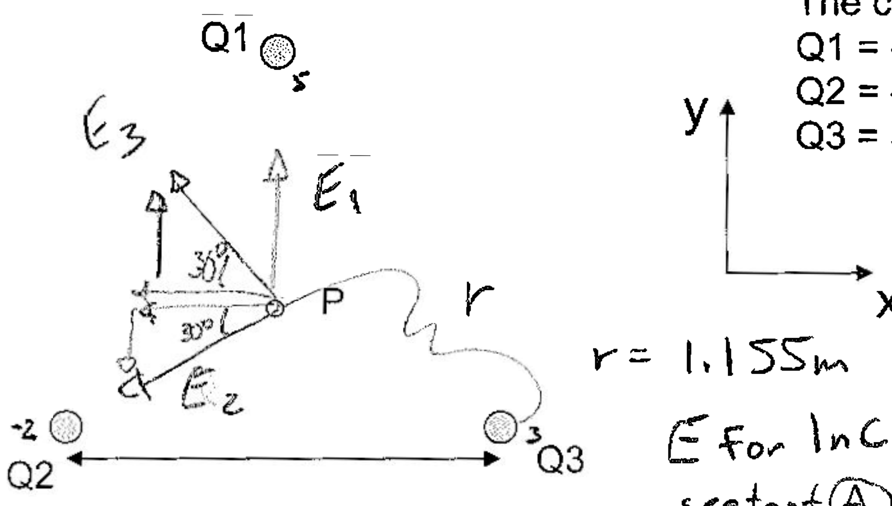
$V_{aB} = \frac{Q_{After}}{7.77pf} = \frac{13.85pC}{7.77pf}$

$= 1.78V$

note $Q_{3pF} \propto V_{AB}$ $\quad 4.62pf \cdot \frac{1.78V}{5V} = 1.64pF$

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

$r = 1.155\,m$

E for $1\,nC = 6.746\ N/C$

see test (A)

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

$\vec{E}_1 = 6.746\frac{N}{C}(5)(0 + \hat{j})$

$\vec{E}_2 = 6.746\frac{N}{C}(2)(-\cos 30°\hat{i} - \sin 30°\hat{j})$

$\vec{E}_3 = 6.746\frac{N}{C}(3)(-\cos 30°\hat{i} + \sin 30°\hat{j})$

$6.746\frac{N}{C}(-1.73 - 2.6\hat{i} + 5 - 1 + 1.5\hat{j})$

Ex= −29.2 N/C	(5)
Ey= 37.1 N/C	(5)

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?

$$V = \frac{\left(9\times10^{-9}\frac{Nm^2}{C^2}\right)(-5nC + 3nC - 2nC)}{1.155\,m}$$

$= -31.2\frac{Nm}{C}$

V at P= −31.2 J/C	(5)
Work = −156 nJ	(5)

$U@\infty = 0$

$U@p = qV = -156\,nJ$

U is lower, E did the work

Physics 116b Test 1 September 21, 2004

Name: Test C Seat:______

This is a 50 minute, closed book examination. Put answers in the boxes provided (if any). If numerical answers are needed, you must include units. Any work needed to justify the answer must be shown in the space provided, or as indicated on a separate piece of paper or elsewhere on the test. **A correct answer without the necessary justifying work may not receive any credit**. You may tear the formula sheet off the back of the exam.

Total points for each problem will appear in the table below and in ( ) beside each problem number. Do what is easiest first. AVOID glancing at anyone else's paper during the exam. No means of communication between other students or outside parties is allowed. **The honor code is in effect.**

You must do all the problems on this test.

Problem	Description	Max Score	Score
1	Short Answer	17	
2	Capacitors	15	
3	E & V	20	
Total		52	

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)

see test A

v = 351 m/s (5)

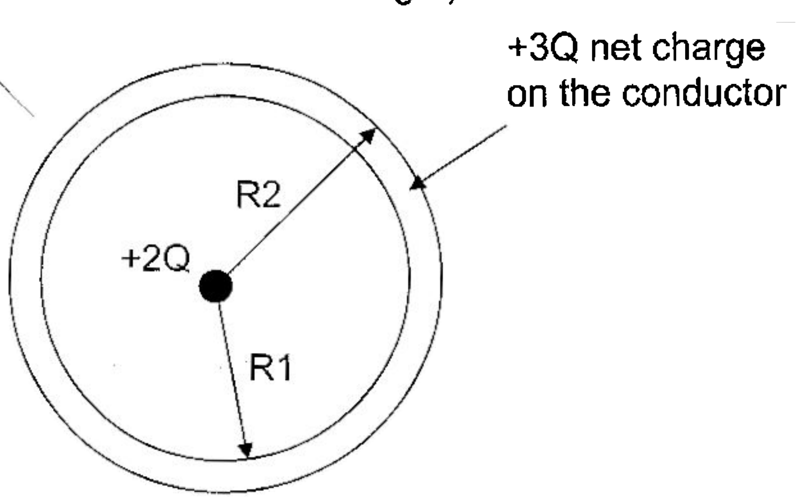
$$V = \frac{2.6C\ 2.7\frac{N}{C}\ 2.0s}{0.04\ kg} = 351\ m/s$$

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/length = 86,400 N/m (5)

$$\frac{F}{l} = \frac{(1.2\times10^{-3}\ C/m)^2\,(9\times10^9\ N\frac{m^2}{C^2})}{(0.3m)}2 = 86,400\ \frac{N}{m}$$

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.)

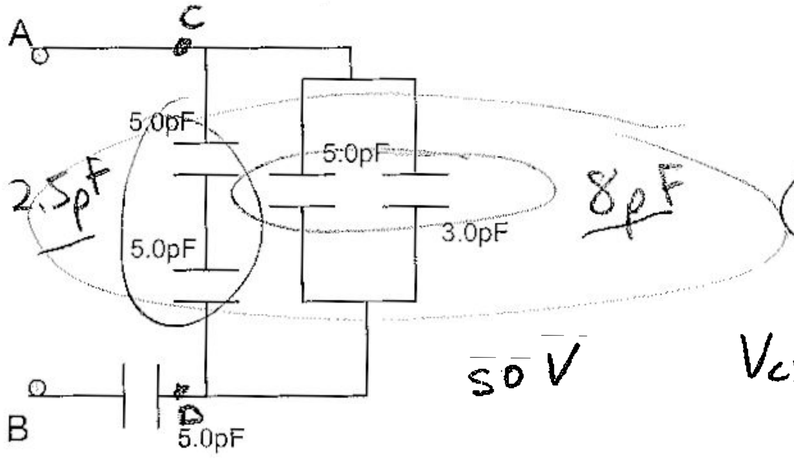


σ at R1 = $\frac{-2Q}{4\pi R1^2}$ (4)

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} = 3.39pF	(5)
Q (on 3pF) = 19.4pC	(5)

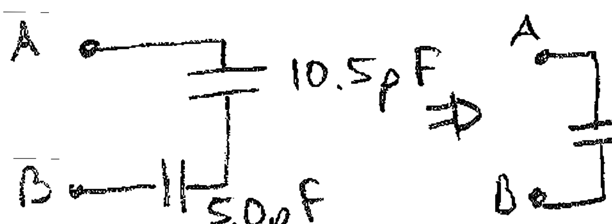


50 V

$$V_{CD} = \frac{Q_{CD}}{C_{CD}} = \frac{67.8pC}{10.5pF} = 6.46V$$

$= V_{across\ 3pF}$

$$Q_{3pF} = 6.46V \cdot 3pF = 19.4pC$$



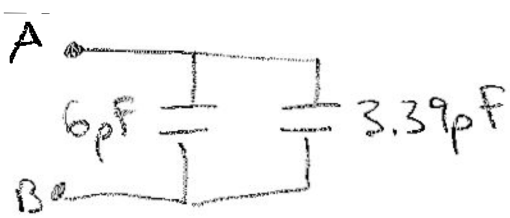
$3.39pF \times 20V =$

$$Q_{AB} = 67.8pC = Q_{CD}$$

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?

$$Q_{Before} = Q_{After}$$

Q (on 3.0pF) = 7pC	(5)



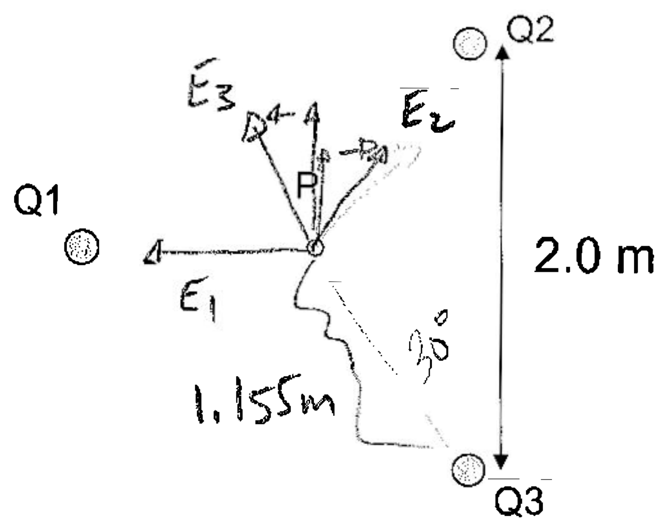
$$V_{AB} = \frac{67.8pC}{9.39pF} = 7.22V$$

$V_{AB} \propto Q_{3pF}$ (see above!)

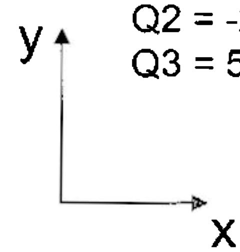
$$(19.4pC)\left(\frac{7.22V}{20V}\right) = 7pC$$

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



for 1nC ①

$E = 6.746\ N/C$

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

Ex= $-37.103\ N/C$	(5)
Ey= $40.9\ N/C$	(5)

$$\vec{E}_1 = 6.746\ N/C(4)\,(-\hat{\imath} + 0)$$
$$\vec{E}_2 = 6.746\ N/C\,(2)\,(\sin 30\hat{\imath} + \cos 30\hat{\jmath})$$
$$\vec{E}_3 = 6.746\ N/C\,(5)\,(\sin 30°(-\hat{\imath}) + \cos 30°\hat{\jmath})$$
$$6.746\ N/C\,[(-4 + 1 - 2.5)\hat{\imath} + (0 + 1.73 + 4.33)\hat{\jmath}]$$

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?

$$V = \frac{\left(9\times10^9 \frac{Nm^2}{C^2}\right)(-4nC - 2nC + 5nC)}{1.155m}$$

V at P= $-7.8\ \frac{Nm}{C}$	(5)
Work = $-46.8\ nJ$	(5)

W

$U_\infty = 0$

$U@p = (6\times10^{-9}C)\left(-7.8\ \frac{Nm}{C}\right) = -46.8nJ$

ΔU negative E did the work!

Physics 116b Test 1   September 21, 2004

Name: Test D   Seat:______

This is a 50 minute, closed book examination. Put answers in the boxes provided (if any). If numerical answers are needed, you must include units. Any work needed to justify the answer must be shown in the space provided, or as indicated on a separate piece of paper or elsewhere on the test. **A correct answer without the necessary justifying work may not receive any credit**. You may tear the formula sheet off the back of the exam.

Total points for each problem will appear in the table below and in ( ) beside each problem number. Do what is easiest first. AVOID glancing at anyone else's paper during the exam. No means of communication between other students or outside parties is allowed. **The honor code is in effect.**

You must do all the problems on this test.

Problem	Description	Max Score	Score
1	Short Answer	17	
2	Capacitors	15	
3	E & V	20	
Total		52	

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)

See test A

v = 354 m/s	(5)

$$V = \frac{(2.5C)(2.5\frac{N}{C})(1.7s)}{0.03\,kg} = 354\,m/s$$

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)

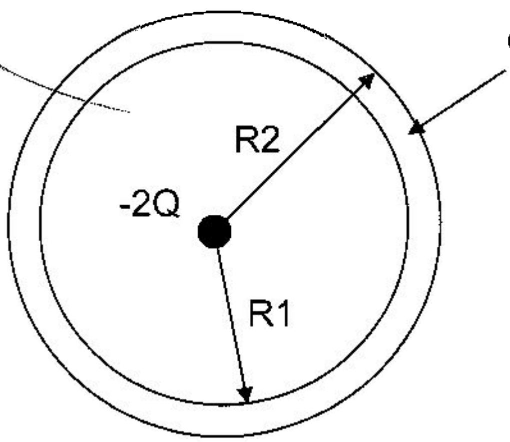
F/length = 67494 N/m	(5)

$$\frac{F}{\ell} = \frac{(9\times10^{-9}\,N\frac{m^2}{C^2})(1.5\times10^{-3}C)^2}{(0.6m)}(2) = 67494\,\frac{N}{m}\,!$$

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.)

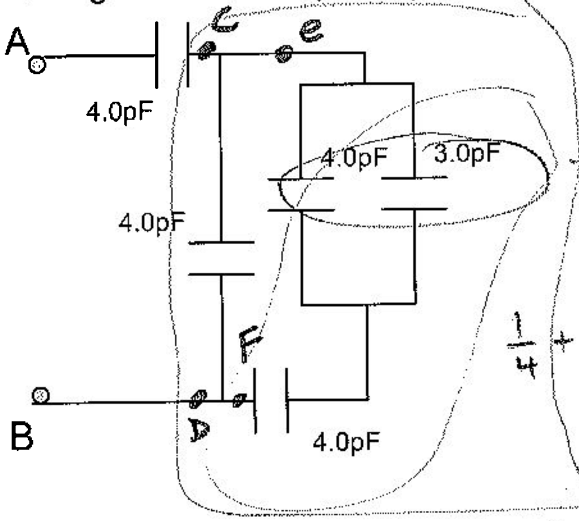
σ at R1 = $\frac{+2Q}{4\pi(R1)^2}$	(4)

+3Q 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 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 pF (5)

Q (on 3pF) = 6.18 pC (5)

7pF

$\frac{1}{4} + \frac{1}{7} = \frac{1}{2.54\,pF} = \frac{1}{C_{eF}}$

$C_{CD} = 6.54\,pF$

$V_{CD} = V_{ef}$

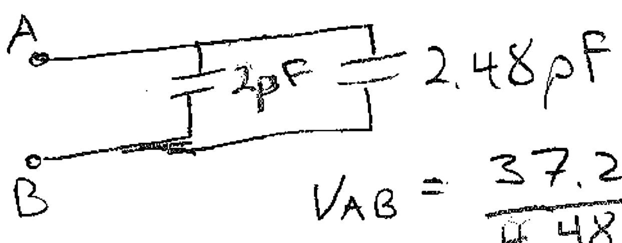
$Q_{ef} = (5.69\,V)\,2.54\,pF = 14.45\,pC$

$V_{7pf} = 14.45\,pC / 7\,pf = V_{3pf}$ so $Q_{3pf} = (2.06\,V)(3\,pf) = 6.18\,pC$

$\frac{1}{C_{AB}} = \frac{1}{4pf} + \frac{1}{6.54pf} \Rightarrow 2.48\,pf$ $\quad Q_{AB} = (15.0V)(2.48pf) = 37.2\,pC = Q_{CD}$ $\quad V_{CD} = \frac{37.2\,pC}{6.54\,pf} = 5.69\,V$

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?

have $\quad Q_{before} = Q_{After} = 37.2\,pC$



Q (on 3.0pF) = 3.42 pC (5)

$V_{AB} = \frac{37.2\,pC}{4.48\,pF} = 8.30\,V$

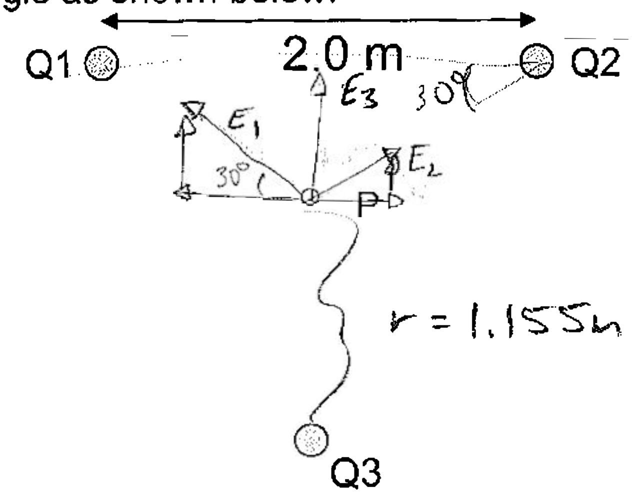
notice above $Q_{3pf} \propto 15.0\,V$!

so $\quad Q_{3pF}^{After} = Q_{3pF}^{before} \frac{V_{ab}^{After}}{V_{ab}^{before}}$

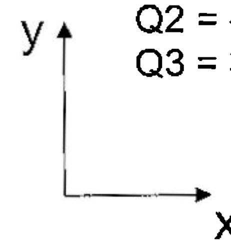
$= 6.18\,pC \left(\frac{8.30V}{15.0V}\right) = 3.42\,pC$

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



E for 1nC = $6.746 \frac{N}{C}$

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

Ex= -17.5 N/C	(5)
Ey= 37.1 N/C	(5)

$\vec{E}_1 = 6.746\frac{N}{C}\,(4)\left(-\cos 30°\,\hat{i} + \sin 30°\,\hat{j}\right)$

$\vec{E}_2 = 6.746\frac{N}{C}\,(1)\left(\cos 30°\,\hat{i} + \sin 30°\,\hat{j}\right)$

$\vec{E}_3 = 6.746\frac{N}{C}\,(3)\left(0\,\hat{i} + \hat{j}\right)$

$6.746\frac{N}{C}\left(-3.46\hat{i} + 0.866\hat{i} + (2.0 + 0.5 + 3.0)\hat{j}\right)$

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

$V = \dfrac{\left(9\times10^{9}\frac{Nm^2}{C^2}\right)\left(-4nC - 1nC + 3nC\right)}{1.155m}$

$= -15.58\frac{Nm}{C}$

V at P= -15.6 Nm/C	(5)
Work = 46.75nJ	(5)

$U @ \infty = 0$

$U @ p = qV = (-3nC)\left(-15.6\frac{Nm}{C}\right)$

$= +46.75nJ$

took energy to bring it to P