1) Short Answer (50 points)(Show Your Work!)

a) If a 0.09 kg particle with charge 1.4 C is placed in an electric field, E=2.3 (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)

$F = qE = ma$ $\quad kg\,m/s^2$

$v = at$

$= \frac{qE}{m}t = \left(\frac{(1.4C)(2.3N/C)}{0.09kg}\right)2.1s = 75.13 m/s$

v = 75 m/s	(5)

b) What is the resistance of a copper wire of length 2.1 m, diameter 1.1 mm, and resistivity of 1.69E-8 Ohm-meters. If this is the resistivity at 20 degrees C, what is the resistance at 42 degrees C?

$R = \rho_0 \frac{l}{A} = \frac{(1.69\times10^{-8}\Omega m)(2.1m)}{\pi(0.0011m/2)^2}$

$= 0.0373\Omega$

$\frac{l}{A}(\rho - \rho_0) = (\rho_0\alpha(T-T_0))\frac{l}{A}$

$R - R_0 = R_0\alpha(T-T_0)$

$R = R_0 + R_0\alpha(T-T_0) = 0.0373\Omega + 0.0373\Omega(4.3\times10^{-3}\frac{}{K})(22°K) = 0.0408\Omega$

R20 = 0.037 Ω	(5)
R42 = 0.041 Ω	(5)

c) A circuit contains un unknown resistor and a charged 15.0 mF capacitor. If the voltage across the 15.0 mF capacitor decreases from 5.5 V at t = 0.0 sec to 4.5 V at 1.5 sec when a switch is closed at t = 0.0 sec, how much current is flowing through the resistor at t = 1.5 sec? Discharging

$Q = Q_0 e^{-t/RC}$

$Q/C = Q_0/C\, e^{-t/RC}$

$V = V_0 e^{-t/RC}$

$\ln\left(\frac{V}{V_0}\right) = -\frac{t}{RC}$

$R = -\frac{t}{C}\frac{1}{\ln\frac{V}{V_0}} = -\frac{1.5s}{.015F}\frac{1}{\ln\frac{4.5}{5.5}}$

$= 498.3\Omega$

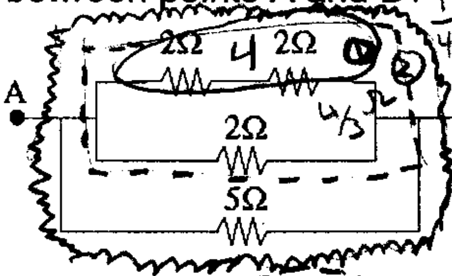
$I = V/R = 4.5V/498.3\Omega$

$= 9.03\times10^{-3}A$

I =	(5)

1) Short Answer (Show Your Work!)

d) Calculate the resistance between points A and B. Now, If I replace each resistor with a capacitor such that 1 Ohm = 1 mF (For example, a 3 Ohm resistor becomes a 3mF capacitor), what is the capacitance between points A and B?

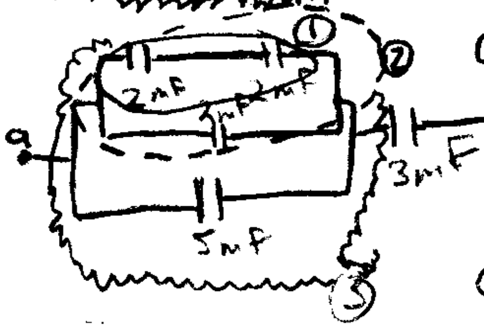


$\frac{1}{4\Omega} + \frac{1}{2\Omega} = \frac{3}{4\Omega}$ ② $R_{②} = \frac{4}{3}\Omega$

③ $\frac{1}{5\Omega} + \frac{3}{4\Omega} = \frac{19}{20\Omega}$

$R_{③} = \frac{20}{19}\Omega \quad R_{ab} = \frac{20}{19}\Omega + 3\Omega = 4.05\ \Omega$

R_{AB} = 4 Ω	(5)
C_{AB} = 2.18 mF	(5)



$C_{①} = 1\text{ mF}$ (from $\left(\frac{1}{2} + \frac{1}{2}\right)^{-1}$)

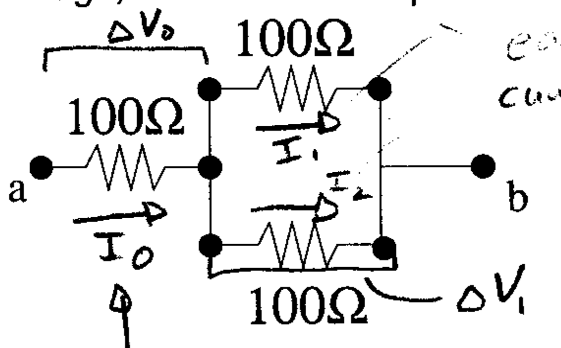
$C_{②} = 3\text{mF}$ (1mF + 2mF)

$C_{③} = 3\text{mF} + 5\text{mF} = 8\text{mF}$

$\frac{1}{C_{ab}} = \frac{1}{8\text{mF}} + \frac{1}{3\text{mF}} = \frac{3}{24\text{mF}} + \frac{8}{24\text{mF}} = \frac{11}{24\text{mF}}$

$C_{ab} = 2.18\text{mF}$

e) Three 100 Ohm resistors are connected as shown below. If the maximum power any one of the resistors can dissipate is 25.0W, what is the maximum voltage that can be applied between the terminals **a** and **b**? At this maximum voltage, what is the total power dissipated by all three resistors? (10pts)



each $\frac{1}{2}I_0$ cause R's the same

V_{ab} = 75.0V	(5)
P_{tot} = 37.5W	(5)

most current through this one

$P = I^2R = 25.0\text{ W}$ — tot

$I_0 = \sqrt{\frac{25.0\text{W}}{100\Omega}} = 0.5\text{A}$

check V^2/R

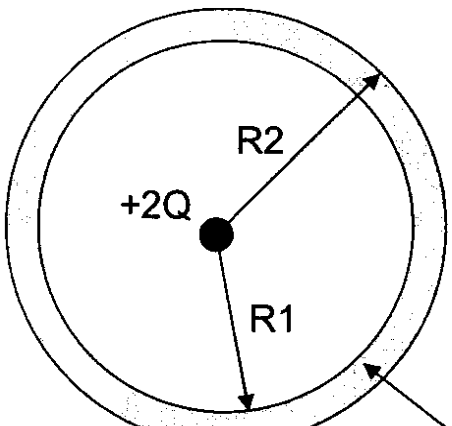
$\Rightarrow \Delta V_0 = (0.5\text{A})(100\Omega) = 50\text{V}$

$\Delta V_1 = \left(\frac{0.5\text{A}}{2}\right)100\Omega = 25\text{ V}$

$P_{\text{due to } V_1} = \frac{V_1^2}{R} + \frac{V_1^2}{R} = 2\frac{(25\text{V})^2}{100\Omega} = 12.5\text{W}$

1) Short Answer (Show Your Work! Explain your reasoning!)

f) 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 suface charge and the outer surface charge is -3Q). What is the electric field inside the shell (r < R1), inside the conductor (R1 < r < R2), and outside the shell (r>R2)? Also, what is the Electric potential inside the shell (r<R1)? (Hint: Remember what E is inside a conductor, that E is a result of total enclosed charge, and that the Electric Potential is 0 at r = infinity.)



$Q_{ins} = +2Q$

symmetry is spherical for whole problem

at electrostat equib. must be $E = 0$

E (inside) =	$\frac{K(2Q)}{r}$	(2)
E (conductor) =	0	(2)
E (outside) =	$\frac{K(-Q)}{r}$	(3)
V (inside) =	$\frac{2KQ}{r} - \frac{2KQ}{R_1} - \frac{KQ}{R_2}$	(3)

→ Q inside Gaussian Surf $= -3Q + 2Q$
$= -Q$

→ Know $V_\infty = 0$

$V_{in\,cond}$ = constant

$V_{outside}$ due to $E_{outside}$ $-\frac{KQ}{r}$

@ cond Surf $V = -\frac{KQ}{R_2}$ & inside cond

Inside has $\frac{K(2Q)}{r}$ plus something

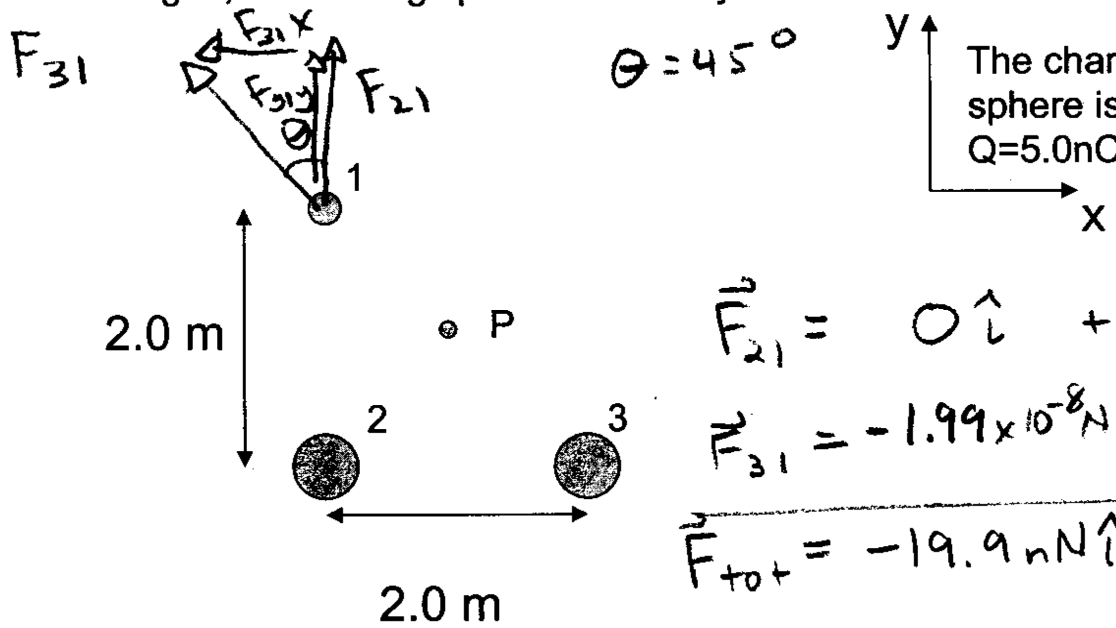
to give $V = -\frac{KQ}{R_2}$ @ $r = R_1$

or $\frac{K(2Q)}{R_1} + V_{need} = -\frac{KQ}{R_2}$

$V_{need} = -\frac{KQ}{R_2} - \frac{K(2Q)}{R_1}$

2) Force and Potential (20 points Show Work!)

3 charged, conducting spheres are arrayed as shown below:



$\vec{F}_{21} = 0\hat{i} + 5.63\times10^{-8}N\hat{j}$

$\vec{F}_{31} = -1.99\times10^{-8}N\hat{i}\ 1.99\times10^{-8}N\hat{j}$

$\vec{F}_{tot} = -19.9nN\hat{i} + 7\ 62nN\hat{j}$

What is the force on the little sphere (1), due to the 2 big spheres (2 & 3)?

$$\vec{F}_{21} = 0\ \hat{i} + \frac{\left(9\times10^{9}\frac{Nm^2}{C^2}\right)(5.0\times10^{-9}C)^2}{(2.0m)^2}$$

$$\vec{F}_{31} = \left[\frac{\left(9\times10^{9}\frac{Nm^2}{C^2}\right)(5.0\times10^{-9}C)^2}{\left(\sqrt{(2m)^2+(2m)^2}\right)^2}\right]\left(-\sin\theta\ \hat{i} + \cos\theta\ \hat{j}\right)$$

Fx= −19.9nN	(5)
Fy= 7 62nN	(5)

What is the Electric potential at a point P, located midway between sphere (1) and sphere (3)? How much work would have to be done to bring in a charge of 5.0nC from infinity to point P?

V at P=95.5 Nm/C	(5)
Work =477nJ	(5)

V is just a sum of the 3

all have equal distance

$$V = 3\frac{KQ}{\sqrt{(1m)^2+(1m)^2}} = 3\frac{\left(9\times10^{9}\frac{Nm^2}{C^2}\right)(5\times10^{-9}C)}{\sqrt{2m^2}} = 95.46 N/C$$

Bring in another positive charge

– charge repelled by others, need to do positive work on charge

$U_\infty = 0 \quad U_p = qV = (5.0\times10^{-9}C)\,95.46\frac{Nm}{C}$

$= 4.77\times10^{-7}Nm$