NAME:______________________ **STUDENT ID NUMBER** ________________

Last, First

1 [5 points] The voltage between the cathode (negatively charged) and the screen of a television set is 22 kV. If we assume a speed of zero for an electron as it leaves the cathode, what is its speed just before it hits the screen? Electron charge is 1.6×10^{-19} C.

A) 8.8×10^{7} m/s

B) 2.8×10^{6} m/s

C) 6.2×10^{7} m/s

D) 7.7×10^{15} m/s

E) 5.3×10^{7} m/s

2 [5 points] The electric field in a region is given by $\vec{E} = 2x^2\,\hat{i} + 3y\,\hat{j}$ where the units are in V/m. What is the potential difference from the origin to (x, y) = (2, 0) m?

A) 8 V

B) –8 V

C) –16/3 V

D) –24/3 V

E) 11 V

3 [5 points] Two charges Q_1 and Q_2 are at rest a distance of 44 cm apart. How much work must be done to slowly move the charges to a separation of 33 cm?

($Q_1 = -4.2 \times 10^{-9}$ C and $Q_2 = -2.2 \times 10^{-9}$ C)

A) -4.4×10^{-7} J

B) -3.3×10^{-9} J

C) 6.3×10^{-8} J

D) -6.3×10^{-7} J

E) 4.4×10^{-7} J

4 [6 points] A ring of radius 5 cm is in the *yz* plane with its center at the origin. The ring carries a uniform charge of 10 nC. The electric potential at x = 12 cm and y = z = 0 cm is approximately

A) 217 V B) 543 V **C) 692 V** D) 809 V E) 963 V

5 [5 points] The metal sphere at the top of a small Van de Graaf generator has a radius of 8.0 cm. How much charge can be accumulated on this sphere before dielectric breakdown of the air around it occurs? (The dielectric strength of air is 3.0 MV/m.)

A) 2.1 μC B) 3.3 μC C) 1.3 nC D) 6.7 μC E) 4.2 μC

6 [6points] A solid conducting sphere of radius r_a is placed concentrically inside a conducting spherical shell of inner radius r_{b1} and outer radius r_{b2}. The inner sphere carries a charge Q while the outer sphere does not carry any net charge. The potential for $r < r_a$ is

A) $kQ\left(\frac{1}{r_a}+\frac{1}{r_{b2}}-\frac{1}{r_{b1}}\right)$

B) $kQ\left(\frac{1}{r_a}-\frac{1}{r_{b2}}+\frac{1}{r_{b1}}\right)$

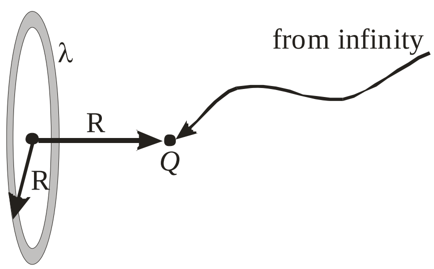
C) $kQ\left(\frac{1}{r_a}-\frac{1}{r_{b2}}\right)$

D) $\frac{kQ}{r}$

E) zero

7 [6points] Calculate the work done to bring a charge, Q = 1 mC, from infinity and place it at a distance R = 10 cm along the axis of a thin uniformly charged ring with linear charge density λ = 10 μC/m and radius R.

A) 564 J B) 282 J C) 127 J **D) 399 J** E) zero



8 [6 points] You connect three capacitors as shown in the diagram below. If the potential difference between A and B is 24.5 V, what is the total energy stored in this system of capacitors if C_1 = 5.0 µF, C_2 = 4.0 µF, and $C_3 = 3.0$ µF?

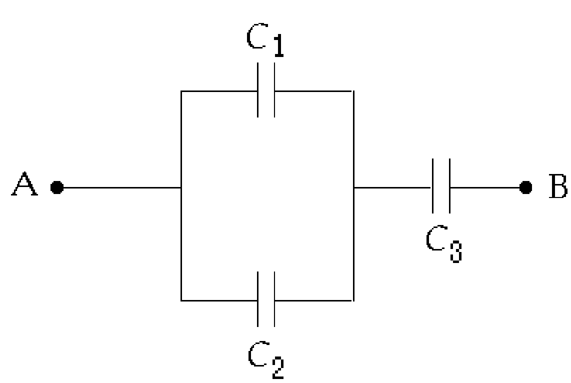
A) 1.7×10^{-4} J

B) 1.5×10^{-4} J

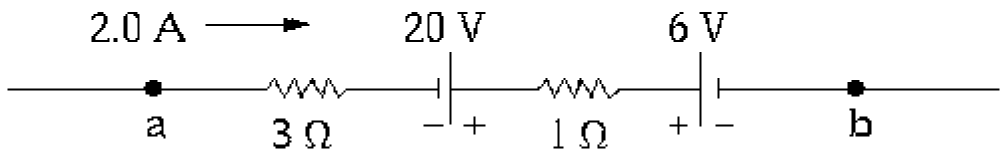
C) 2.2×10^{-5} J

D) 6.8×10^{-4} J

E) 4.0×10^{-4} J

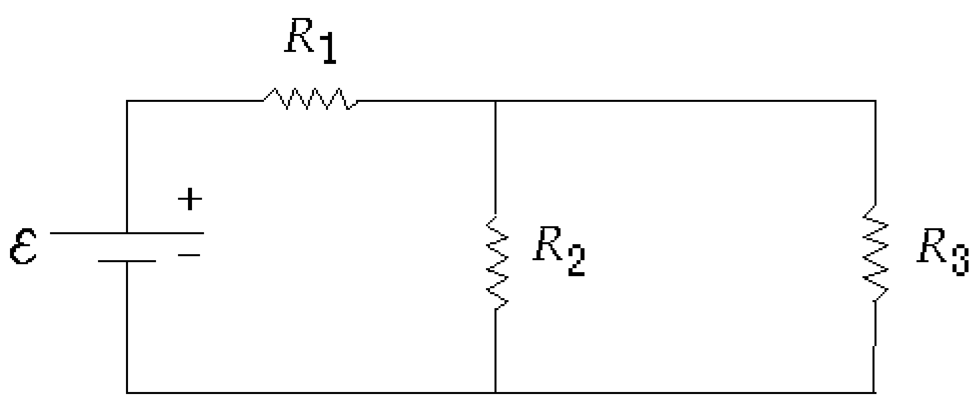


9 [5 points] If a current of 2.0 A is flowing from point a to point b, the potential difference between the points is



A) 6 V B) 8 V C) 14 V D) 20 V E) 22 V

10 [6 points] A comparison of the power losses (P_1, P_2, or P_3) in the resistors of the circuit in the diagram shows that, if $R_1 = R_2 = R_3$,



A) $4P_1 = P_2 = P_3$

B) $P_1 = 2P_2 + 2P_3$

C) $P_1 = P_2 = P_3$

D) $P_1 = (1/2)P_2 = (1/2)P_3$

E) $P_1 = P_2 + P_3$

11. [25 points] Consider two identical parallel-plate capacitors C_1 =1pF and C_2 that are connected in parallel. In between the plates of capacitor C_1 there is air (which has basically the same permittivity as vacuum) while the capacitor C_2 has a dielectric and C_2=3C_1. A 200 V battery is connected across the combination until electrostatic equilibrium is established, and then the battery is disconnected. In all answers please show your work.

a) What is the positive charge on each capacitor?

$$Q_1 = C_1 V = 2\times10^{-10} C$$
$$Q_2 = C2V = 6\times10^{-10} C$$

b) What is the total stored energy of the capacitors?

$$U_b = \frac{1}{2}Q_1 V + \frac{1}{2}Q_2 V = 8\times10^{-8} J$$

c) The dielectric is removed from C_2. What is the total stored energy of the capacitors?

$$Q_1^{new} = Q_2^{new} = \frac{Q_1 + Q_2}{2}$$
$$U_c = \frac{\left(Q_1^{new}\right)^2}{2C_1} + \frac{\left(Q_2^{new}\right)^2}{2C_2} = 16\times10^{-8} J$$

d) If the total energy changes, explain the reason for the change.

One had to extract the dielectric and perform work on the system (similarly to lifting a weight).

e) What is the final voltage across the two capacitors?

$$V_1^{new} = V_2^{new} = \frac{Q_1^{new}}{C_1} = 400V$$

Name ___________________________________ **Student ID** _______________ **Score** ___________
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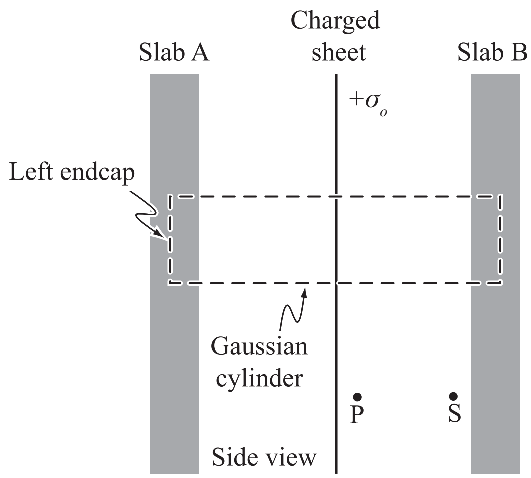
IV. [20 points total] An infinite, uniformly charged sheet, with positive charge density σ_o, is placed halfway between two infinite thick conducting slabs. Each slab has zero net charge.



The Gaussian cylinder shown has each end cap within a conducting slab and the cylinder has its axis perpendicular to the charged sheet. For each portion of the Gaussian surface, use area vectors consistent with fact that the entire surface is closed.

A. [5 pts] Is the flux through the left end cap *greater than, less than,* or *equal to* zero? Explain your reasoning.

The left end cap is inside of a conductor. The electric field inside of a conductor is zero. Since flux is proportional to electric field, the flux through the left end cap is zero.

B. [5 pts] Is the net flux through the entire cylinder *greater than, less than,* or *equal to* zero? Explain.

Since the system consists of infinite sheets, the electric field vectors must be parallel to the cylinder's axis. Therefore, at any point on the curved side of the cylinder, E and dA are perpendicular, making the flux through the curved side of the cylinder zero. By the same argument used in part A, the flux through each end cap is zero. Adding these we find a net flux of zero.

C. [5 pts] Write an expression for the charge density induced on the left side of slab B, $\sigma_{\text{L of B}}$, in terms of σ_o. If there is no charge density induced on the left side of slab B, state so explicitly.

If you don't have enough information to find an expression for $\sigma_{\text{L of B}}$, explain what additional information you need. Explain your reasoning.

From part B we know that the net flux through the Gaussian cylinder is zero. From Gauss' law, the total enclosed charge is zero. A charge $+\sigma_0 A$ *from the sheet is enclosed. The induced charges on the right surface of slab A and the left surface of slab B will also be enclosed. Since the system is symmetric under reflections through the sheet,* $\sigma_{R\,of\,A} = \sigma_{L\,of\,B}$. *Putting this all together we find* $\sigma_0 A + \sigma_{R\,of\,A} A + \sigma_{L\,of\,B} A = \sigma_0 A + 2\sigma_{L\,of\,B} A = 0$, *which implies that* $\sigma_{L\,of\,B} = -\sigma_0/2$.

D. [5 pts] Is the potential at point P *greater than, less than,* or *equal to* the potential at point S? Explain.

We may treat the surface charges on the slabs as infinite sheet charges. The two conducting slabs are neutral, so the contributions from each side of a particular slab cancel to zero. This leaves just the electric field due to the charged sheet, so in the region between the sheet and slab B, the electric field points to the right. Thus, in moving a positive charge in a straight line from P to S, the electric field does positive work. Since $\Delta V=-W/q$ *we see that* $\Delta V<0$. *Therefore, the potential at point P is greater than the potential at point S.*