NAME:_____

Exam 2
March 29, 2019

Some direction:

No phones or other device that connects to the internet.

You may use a calculator, and I would prefer you to plug in numerical answers and keep three sig figs regardless of the correct number of sig figs in the problem.

Present clear and complete answers:

Explain your answers clearly but briefly. You want to aim for a level of solution that someone taking this class would be able to understand. A diagram and a few words may help.

Start calculations with first principles: things like definitions ($\vec{E} \equiv \frac{\vec{F}}{Q}$) or empirical laws (like Coulomb's Law or Newton's Laws) or conservation laws.

Check time:

The point values for each problem are shown next to the question number. Time yourself accordingly. The total value of the exam is 100 points. **Good luck!**

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Some constants:

$$K = k = \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 Nm^2/C^2 \approx 9 \times 10^9 Nm^2/C^2$$

$$\epsilon_0 = 8.85 \times 10^{-12} C^2/N/m^2$$

$$e = 1.6 \times 10^{-19} C$$

Helpful Equations:

$$\Phi \equiv \int \vec{E} \cdot d\vec{A}$$

$$E_i = E_f$$

$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{enc}}{\epsilon_0}$$

$$E = K + U$$

Definitions	Point charges	Uniform $\vec{E}$
	$\lvert\vec{F}\rvert = k\frac{\lvert qQ\rvert}{r^2}$	$\vec{F} = Q\vec{E}$
$\vec{E} \equiv \frac{\vec{F}}{Q}$	$\lvert\vec{E}\rvert = k\frac{\lvert q\rvert}{r^2}$	$\vec{E} = const$
$\Delta U \equiv -W$	$U = k\frac{qQ}{r}$	$\Delta U = QEs$
$V \equiv \frac{U}{Q}$	$V = k\frac{q}{r}$	$\Delta V = Es$

$$C \equiv \frac{|Q|}{|V|}$$

$$C = \epsilon_0 \frac{A}{d}$$

$$W = \frac{1}{2}CV^2$$

$$I = \frac{dQ}{dt} = \frac{\Delta Q}{\Delta t}$$

$$V = IR$$

$$R_{eq} = R_1 + R_2 + ...$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + ...$$

$$q(t) = Q_{max}(1 - e^{-\frac{t}{RC}})$$

$$q(t) = Q_{max} e^{-\frac{t}{RC}}$$

$$dq = \lambda d\ell$$

$$dq = \sigma da = \eta da$$

$$dq = \rho dV$$

$$P = IV$$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + ...$$

$$C_{eq} = C_1 + C_2 + \ldots$$

NAME:_____

1. (5 points) A 2μF capacitor is connected in series with a 4kΩ resistor and a 12V battery. What is the time constant for charging this capacitor in this circuit?

2. (5 points) Is it possible to have $\vec{E} = 0$ and $V \neq 0$ at some point? If yes, give an example; if no, explain why not.

3. (5 points) A circuit is composed of a battery and two resistors. Which configuration would pull more current from the battery: the two resistors in series or parallel? Why?

4. (10 points) A 4kΩ resistor and a 2kΩ resistor are connected in series with a 12V battery. What is the voltage drop across the 2kΩ resistor?

5. (15 points) A parallel plate capacitor consists of two plates, each with area 0.5 m^2 and charge of magnitude 2μC, and a separation between the plates of 1 mm.

   (a) What is the capacitance of this configuration?

   (b) What is the potential difference between the plates?

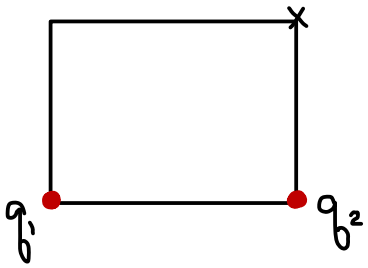
   (c) Calculate the value of the electric field between the plates.

   (d) If you double the charge on the plates, what happens to the capacitance?

6. (15 points) Two point charges are located on the bottom two corners of a 8cm $\times$ 6cm rectangle. $q_1 = 5\mu$C and $q_2 = -6\mu$C.

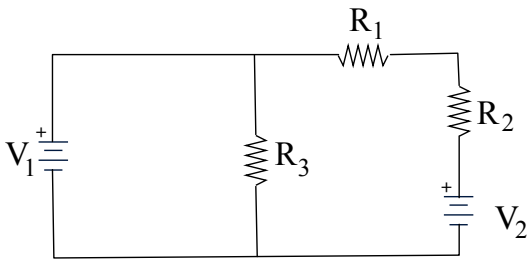
   (a) Find the potential at the upper right corner (marked with an X).

   (b) How much work does it take to bring a third charge, $q_3 = 3\mu$C from infinity and place it at the same corner (marked by the X)?



7. (10 points) An insulating sphere of radius R carries a total charge $+Q$ that is distributed evenly throughout the volume of the sphere. Derive an expression for the electric field inside the sphere ($r < R$).

8. (20 pts) For the circuit shown below, $V_1 = 9\text{V}$, $V_2 = 12\text{V}$, $R_1 = 1\text{k}\Omega$, $R_2 = 2\text{k}\Omega$, $R_3 = 3\text{k}\Omega$



   (a) Find the current through each of V_1, R_3, and R_2.

   (b) Find the power dissipated in R_2.

9. (15 pts) A spherical capacitor can be made by placing one charged sphere inside another. Imagine an inner sphere of radius a with charge $+Q$ uniformly distributed on its surface, and a concentric, outer sphere of radius b with charge $-Q$ uniformly distributed on its surface.

   (a) Derive an expression for the electric field between the spheres. ($a < r < b$)

   (b) Use your expression for $\vec{E}$ from part (a) to find ΔV between the spheres.

   (c) What is the capacitance of this arrangement?