UNIVERSITY OF ALABAMA
Department of Physics and Astronomy

PH 102 Spring 2015

Exam 1

Instructions

1. Solve three of the four problems below.
2. All problems have equal weight. Do your work on separate sheets.
3. You are allowed 1 sheet of standard 8.5×11 in paper and a calculator.

□ **1.** Consider the arrangement of four charges below, all of magnitude q. **(a)** Find the electric field, both direction and magnitude, at the center. **(b)** Find the electric potential at the center. **(c)** What is the potential energy of this arrangement of charges? **(d)** Is this a stable arrangement of charges? Explain your answer.

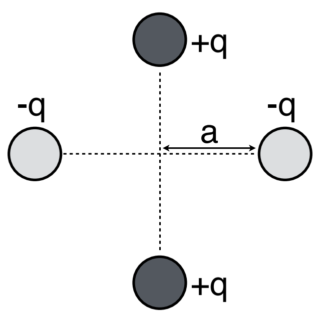

Figure 1: *Problem 1*

□ **2.** A charge q_1 and a charge q_2 are separated by a distance of $d = 0.1\,\text{m}$. For the sake of concreteness, let q_1 be at $x=0$ and q_2 at $x=0.1\,\text{m}$. *Note: not all parts below require calculation.*

a) If $q_1 = 5.0\,\mu\text{C}$ and $q_2 = 10.0\,\mu\text{C}$, find a location where $E=0$.

b) If we take the convention that $V=0$ an infinite distance from the charges, is there another place a finite distance away where $V=0$ in the situation from part a? If so, find one.

c) If we now take q_2 to be negative, $q_2 = -10.0\,\mu\text{C}$, is there a place where $V=0$? If so, find one.

□ **3.** **(a)** Find the equivalent capacitance for the combination of capacitors shown on the next page. **(b)** How much charge is stored in total? **(c)** How much energy is stored in total? **(d)** How much charge is on the bottom $1\,\mu\text{F}$ capacitor?

□ **4.** Two spherical cavities, of radii a and b, are hollowed out from the interior of a neutral conducting sphere of radius R as shown in the figure below. At the center of each cavity a point charge is placed: q_a and q_b.

a) Find the surface charge on the inside of each cavity and on the outside of the conducting sphere.

b) What is the field outside the conductor?

c) What is the field within each cavity?

d) What is the force on q_a and q_b?

e) Which of these answers would change if a third charge, q_c, were brought near the conductor (but outside of it)?

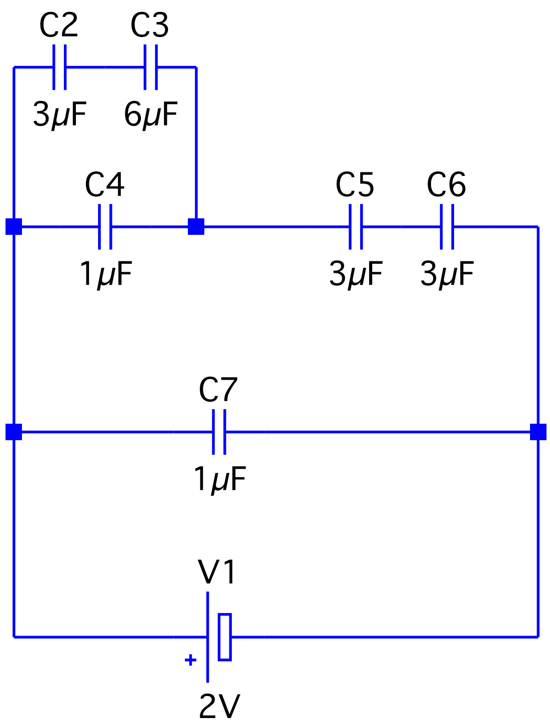

Figure 2: *Problem 3*

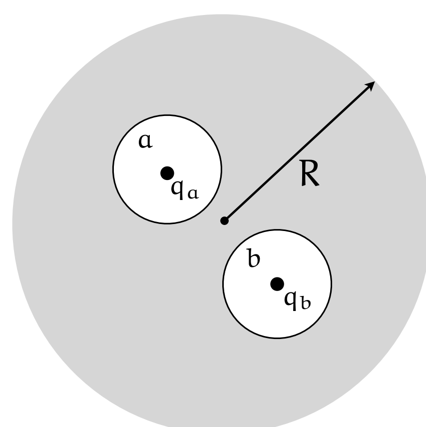

Figure 3: *Problem 4*

Formula sheet

Constants:

$$k_e \equiv 1/4\pi\epsilon_o = 8.98755 \times 10^9 \text{ N}\cdot\text{m}^2\cdot\text{C}^{-2}$$
$$\epsilon_o = 8.85 \times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2$$
$$e = 1.60218 \times 10^{-19} \text{ C}$$
$$m_e = 9.10938 \times 10^{-31} \text{ kg}$$

Quadratic formula:

$$0 = ax^2 + bx^2 + c \Longrightarrow x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Basic Equations:

$$\vec{\mathbf{F}}_{\text{net}} = = m\vec{\mathbf{a}} \quad \text{Newton's Second Law}$$
$$\vec{\mathbf{F}}_{\text{centr}} = -\frac{mv^2}{r}\hat{\mathbf{r}} \quad \text{Centripetal}$$

Vectors:

$$|\vec{\mathbf{F}}| = \sqrt{F_x^2 + F_y^2} \quad \text{magnitude}$$
$$\theta = \tan^{-1}\left[\frac{F_y}{F_x}\right] \quad \text{direction}$$

Unit	Symbol	equivalent to
newton	N	kg·m/s^2
joule	J	kg·m^2/s^2 = N·m
watt	W	J/s=m^2·kg/s^3
coulomb	C	A·s
amp	A	C/s
volt	V	W/A = m^2·kg/·s^3·A
farad	F	C/V = A^2·s^4/m^2·kg
ohm	Ω	V/A = m^2·kg/s^3·A^2
-	1 N/C	1 V/m

Power	Prefix	Abbreviation
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m
10^{-2}	centi	c
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T

Electric Potential:

$$\Delta V = V_B - V_A = \frac{\Delta\text{PE}}{q}$$
$$\Delta PE = q\Delta V = -q|\vec{\mathbf{E}}||\Delta\vec{\mathbf{x}}|\cos\theta = -qE_x\Delta x$$
$$\uparrow \text{ constant E field}$$
$$V_{\text{point charge}} = k_e\frac{q}{r} = \frac{q}{4\pi\epsilon_o r}$$
$$PE_{\text{pair of point charges}} = k_e\frac{q_1q_2}{r_{12}}$$
$$PE_{\text{system}} = \text{sum unique pairs} = \sum_{\text{pairs } ij}\frac{k_eq_iq_j}{r_{ij}}$$
$$-W = \Delta\text{PE} = q(V_B - V_A)$$

Electric Force & Field

$$\vec{\mathbf{F}}_{e,12} = q\vec{\mathbf{E}}_{12} = \frac{k_eq_1q_2}{r_{12}^2}\hat{\mathbf{r}}_{12} = \frac{q_1q_2}{4\pi\epsilon_o r_{12}^2}\hat{\mathbf{r}}_{12}$$
$$\vec{\mathbf{E}} = k_e\frac{|q|}{r^2} = \frac{|q|}{4\pi\epsilon_o r^2}$$
$$\Phi_E = |\vec{\mathbf{E}}|A\cos\theta_{EA} = \frac{Q_{\text{enclosed}}}{\epsilon_0} \quad \text{Gauss}$$
$$\Delta PE = -W = -q|\vec{\mathbf{E}}||\Delta\vec{\mathbf{x}}|\cos\theta = -qE_x\Delta x$$
$$\uparrow \text{ constant E field}$$

Capacitors:

$$Q_{\text{capacitor}} = C\Delta V$$
$$C_{\text{parallel plate}} = \frac{\epsilon_0 A}{d}$$
$$E_{\text{capacitor}} = \frac{1}{2}Q\Delta V = \frac{Q^2}{2C}$$
$$C_{\text{eq, par}} = C_1 + C_2$$
$$\frac{1}{C_{\text{eq, series}}} = \frac{1}{C_1} + \frac{1}{C_2}$$
$$C_{\text{with dielectric}} = \kappa C_{\text{without}}$$
$$U = PE = \frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$$