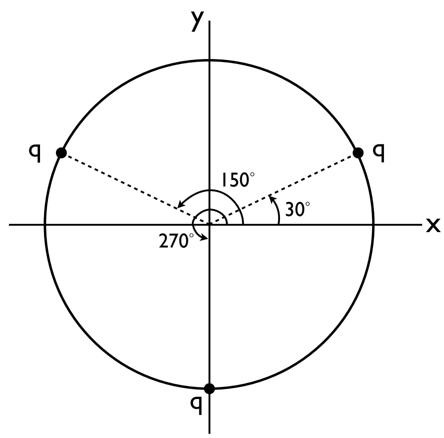
Name & CWID

PH 102 Exam I

1. **Answer six of the eight questions below.** All problems have equal weight.
2. Using the tick boxes, clearly mark your which problems you have chosen.
3. You are allowed 2 sides of a standard 8.5x11 in piece of paper and a calculator.

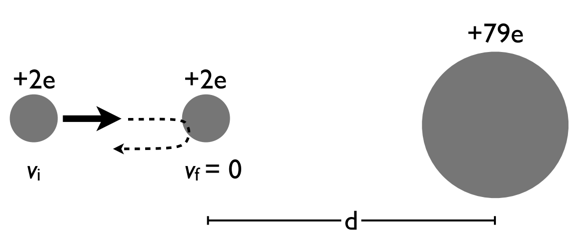
□ **1.** Three identical charges of $q = -5.0\,\mu C$ lie along a circle of radius 2.0 m at angles of 30°, 150°, and 270° as shown below. What is the resultant electric field at the center of the circle?



□ **2.** If the electric field strength in air exceeds 3.0×10^6 N/C, the air becomes a conductor and current may flow (i.e., a spark occurs). Using this fact, determine the maximum amount of charge that can be carried by a metal sphere 2.0 m in radius. *Hint:* recall that from Gauss' law that for points outside a spherically-symmetric charge distribution, the electric field is identical to a point charge at the center of the sphere.

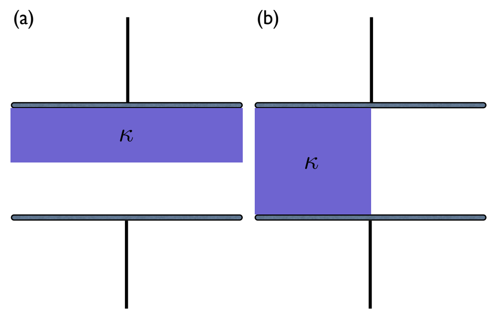
□ **3.** Four point charges each having charge Q are located at the corners of a square having sides of length a. What is the total potential energy of this system?

□ **4.** In Rutherford's famous scattering experiments that led to the planetary model of the atom, alpha particles (having charge $+2e$ and masses of 6.64×10^{-27} kg) were fired toward a gold nucleus with charge $+79e$. An alpha particle, initially very far from the gold nucleus, is fired at a speed of $v_i = 2.00 \times 10^7$ m/s directly toward the nucleus, as shown below. How close does the alpha particle get to the gold nucleus before turning around? Assume the gold nucleus remains stationary, and that energy is conserved.

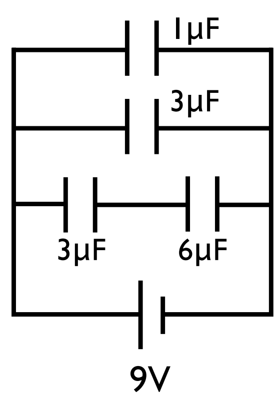


Name & CWID

□ 5. A parallel plate capacitor has a capacitance C when there is vacuum between the plates. The gap between the plates is half filled with a dielectric with dielectric constant κ in two different ways, as shown below. Calculate the effective capacitance, in terms of C and κ, for both situations. *Hint: try breaking each situation up into a combination of two separate capacitors.*



□ **6.** Find **(a)** the equivalent capacitance of this circuit, and **(b)** the total charge stored in this circuit. Note $\mu = 10^6$.



□ **7.** In a time interval of 7.00 s, the amount of charge that passes through a light bulb is 2.51 C. **(a)** What is the current in the bulb? **(b)** How many electrons pass through the bulb in 5.00 sec?

□ **8.** A 0.05 kg sample of a conducting material is all that is available. The resistivity of the material is measured to be $1.1 \times 10^{-7}\ \Omega\,\mathrm{m}$, and its density is $7860\,\mathrm{kg/m^3}$. The material is to be shaped into a solid cylindrical wire that has a total resistance of $1.5\,\Omega$. What length and diameter of wire are required?

Constants:

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

Quadratic formula:

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

Basic Equations:

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

Vectors:

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

Current:

$$I = \frac{\Delta Q}{\Delta t} = nqAv_d$$
$$v_d = \frac{e\tau}{m}E \quad \tau = \text{scattering time}$$
$$\rho = \frac{m}{ne^2\tau}$$
$$\Delta V = \frac{\rho l}{A} I = RI$$
$$R = \frac{\Delta V}{I} = \frac{\rho l}{A}$$
$$\mathscr{P} = E \cdot \Delta t = I\Delta V = I^2 R = \frac{[\Delta V]^2}{R} \quad \text{power}$$

Ohm:

$$\Delta V = IR$$
$$\mathscr{P} = E \cdot \Delta t = I\Delta V = I^2 R = \frac{[\Delta V]^2}{R} \quad \text{power}$$

Electric Potential:

$$\Delta V = V_B - V_A = \frac{\Delta PE}{q}$$
$$\Delta PE = q\Delta V = -q|\vec{E}||\Delta\vec{x}|\cos\theta = -qE_x\Delta x$$
$$\uparrow \ \text{constant E field}$$
$$V_{\text{point charge}} = k_e\frac{q}{r}$$
$$PE_{\text{pair of point charges}} = k_e\frac{q_1 q_2}{r_{12}}$$
$$PE_{\text{system}} = \text{sum unique pairs} = \sum_{\text{pairs } ij} \frac{k_e q_i q_j}{r_{ij}}$$
$$-W = \Delta PE = q(V_B - V_A)$$

Electric Force & Field

$$\vec{F}_{e,12} = q\vec{E}_{12} = \frac{k_e q_1 q_2}{r_{12}^2}\hat{r}_{12}$$
$$\vec{E} = k_e\frac{|q|}{r^2}$$
$$\Phi_E = |\vec{E}|A\cos\theta_{EA} = \frac{Q_{\text{inside}}}{\epsilon_0} \quad \text{Gauss}$$
$$\Delta PE = -W = -q|\vec{E}||\Delta\vec{x}|\cos\theta = -qE_x\Delta x$$
$$\uparrow \ \text{constant E field}$$

Capacitors:

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

Unit	Symbol	equivalent to
newton	N	$\mathrm{kg\cdot m/s^2}$
joule	J	$\mathrm{kg\cdot m^2/s^2} = \mathrm{N\cdot m}$
watt	W	$\mathrm{J/s = m^2\cdot kg/s^3}$
coulomb	C	$\mathrm{A\cdot s}$
amp	A	C/s
volt	V	$\mathrm{W/A = m^2\cdot kg/\cdot s^3\cdot A}$
farad	F	$\mathrm{C/V = A^2\cdot s^4/m^2\cdot kg}$
ohm	Ω	$\mathrm{V/A = m^2\cdot kg/s^3\cdot A^2}$
-	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