Key

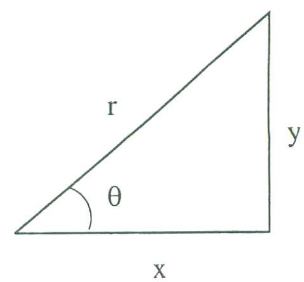
Physics 241 – Exam #1

February 24 **2005**

This exam consists of 13 problems on 9 pages. **Please check that you have them all.** Each problem is worth 8 points unless otherwise noted.

All of the formulas that you will need are given below. You may also use a calculator.

$\sin\theta = y/r$ $\cos\theta = x/r$ $\tan\theta = y/x$



$e = 1.6\times10^{-19}$ C $k = 9.0\times10^{9}\ \mathrm{N\cdot m^2/C^2}$ $\epsilon_0 = 8.9\times10^{-12}\ \mathrm{C^2/(N\cdot m^2)}$

$$F = \frac{kq_1q_2}{r^2} = \frac{q_1q_2}{4\pi\epsilon_0 r^2} \qquad E = \frac{kq}{r^2} \qquad \Phi = \int \vec{E}\cdot d\vec{A} = \frac{q}{\epsilon_0} \qquad \text{charged plane}: E = \frac{\sigma}{2\epsilon_0}$$

$$\Delta V = \frac{\Delta U_E}{q} = -\int \vec{E}\cdot d\vec{l} \qquad dV = -\vec{E}\cdot d\vec{l} \qquad \text{point charge}: V = \frac{kq}{r} \qquad U_E = q_0V = \frac{kqq_0}{r}$$

$$E_x = -\frac{\partial V}{\partial x} \qquad 1\text{ Volt} = 1\text{ J / C} \qquad 1\text{ Volt/m} = 1\text{ N / C} \qquad U_E = \frac{1}{2}qV \qquad C = \frac{q}{V}$$

$$\text{Surface area(sphere)} = 4\pi R^2 \qquad \text{capacitor}: U_E = \frac{1}{2}\frac{q^2}{C} = \frac{1}{2}qV = \frac{1}{2}CV^2 \qquad u_E = \frac{1}{2}\epsilon_0E^2$$

$$\text{parallel plate capacitor}: C = \frac{\epsilon_0A}{d} \qquad \text{isolated spherical capacitor}: C = 4\pi\epsilon_0R$$

$$\text{capacitors in parallel}: C = C_1 + C_2 + C_3\ldots \qquad \text{capacitors in series}: \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\ldots$$

$$C = \kappa C_0 \qquad I = \frac{\Delta q}{\Delta t} \qquad R = \frac{V}{I} \qquad R = \rho\frac{L}{A} \qquad V = IR$$

$$P = IV = I^2R = \frac{V^2}{R} \qquad P = \mathcal{E}I \qquad \text{resistors in series}: R = R_1 + R_2 + R_3 ...$$

$$\text{resistors in parallel}: \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} ... \qquad q(t) = q_0 e^{-t/(RC)} = q_0 e^{-t/\tau}$$

$$I(t) = \frac{V}{R}e^{-t/(RC)} = I_0 e^{-t/\tau} \qquad \tau = RC$$

$$q(t) = C\mathcal{E}(1 - e^{-t/(RC)}) = q_0(1 - e^{-t/\tau}) \qquad I(t) = \frac{\mathcal{E}}{R}e^{-t/(RC)} = I_0 e^{-t/\tau}$$

1. A point charge $q_1 = -1.5$ C is at the origin, and a second point charge $q_2 = +5.0$ C is at the point $x = 1.2$ m, $y = 2.5$ m. Find the x and y coordinates of the position at which an electron would be in equilibrium.

   (a) $x = -3.3$ m, $y = -2.7$ m

   (b) $x = -1.4$ m, $y = -3.0$ m

   (c) $x = -3.3$ m, $y = 0.0$ m

   (d) $x = +1.4$ m, $y = +3.0$ m

   (e) $x = -0.62$ m, $y = -1.3$ m

2. A metal sphere of radius r is placed at the center of a cubical box with a side length of L (and with $L \gg r$). If 10 excess electrons are placed on the sphere, what is the magnitude of the electric flux through one face of the box?

   (a) 3.0×10^{-8} N $\cdot$ m^2/C

   (b) 5.9×10^{-8} N $\cdot$ m^2/C

   (c) 1.8×10^{-7} N $\cdot$ m^2/C

   (d) 1.8×10^{-8} N $\cdot$ m^2/C

   (e) zero

3. A parallel plate capacitor is connected to a battery of unknown voltage for a very long time. The capacitor is then disconnected and the separation between its plates is increased by a factor of 3. It is then found that the charge on the plates is $\pm 35\ \mu$C, while the final capacitance is 2000×10^{-12} F. What was the battery voltage?

(a) 110 V

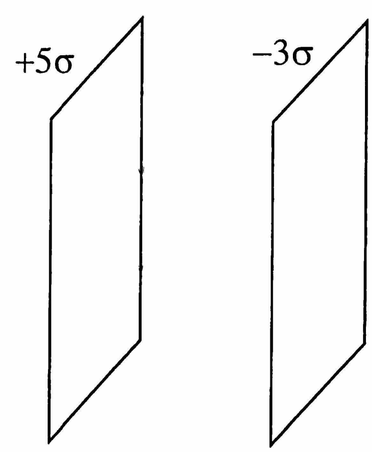
(b) 70 V

(c) 58 V

(d) 5800 V

(e) 1700 V

4. Two infinite charged planes have charge densities $+5\sigma$ and -3σ. If $\sigma > 0$, what is the electric field between the planes?



(a) $4\sigma/\epsilon_0$ directed to the left

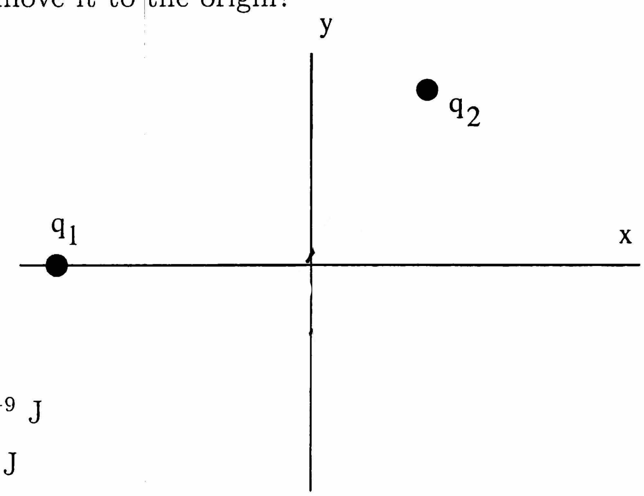
(b) $\sigma/2\epsilon_0$ directed to the right

(c) $4\sigma/\epsilon_0$ directed to the right

(d) $2\sigma/\epsilon_0$ directed to the right

(e) σ/ϵ_0 directed to the right

5. Two point charges are located as shown below. $q_1 = +2.5$ C and is at $x = -3.0$ m, $y = 0$, while $q_2 = +4.0$ C and is at $x = +1.0$ m, $y = +2.0$ m. An electron is now taken from a point very far away and placed at the origin. How much work must be done on the electron to move it to the origin?



(a) -6.6×10^{-9} J

(b) 6.6×10^{-9} J

(c) -5.5×10^{-9} J

(d) -3.8×10^{-9} J

(e) -1.6×10^{-9} J

6. Consider again the two point charges in Problem 5. What are the components the electric field at $x = +1.0$ m, $y = 0$?

(a) $E_x = 5.6 \times 10^9$ V/m, $E_y = -4.5 \times 10^9$ V/m

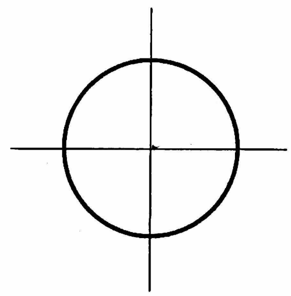
(b) $E_x = 5.6 \times 10^9$ V/m, $E_y = 1.4 \times 10^9$ V/m

(c) $E_x = 1.4 \times 10^9$ V/m $E_y = -9.0 \times 10^9$ V/m

(d) $E_x = -3.9 \times 10^9$ V/m, $E_y = -7.2 \times 10^9$ V/m

(e) $E_x = 5.6 \times 10^9$ V/m, $E_y = -1.8 \times 10^{10}$ V/m

7. A circular ring of charge has a radius R and a charge per unit length λ. What is the electric potential at the center of the ring? Take $V = 0$ at infinity.



(a) $2\pi\lambda k/R$

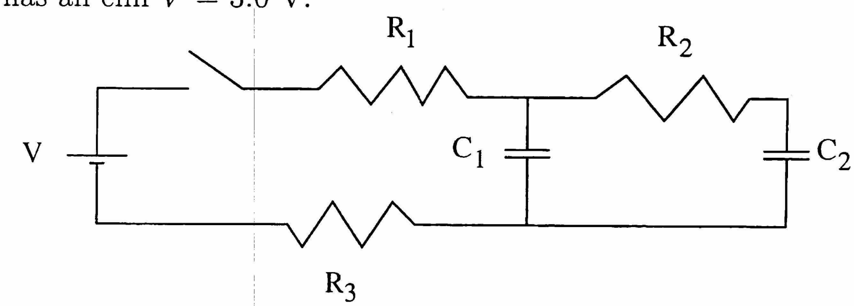
(b) $\lambda k/R$

(c) $2\pi\lambda/R$

(d) zero

(e) $2\pi\lambda k$

8. The switch in this $R - C$ circuit is initially open and the capacitors are uncharged. What is the current through R_1 immediately after the switch is closed? Assume that $R_1 = 1500\ \Omega$, $R_2 = 2500\ \Omega$, $R_3 = 4500\ \Omega$, $C_1 = 2.5$ F, and $C_2 = 1.5$ F, and that the battery has an emf $V = 3.0$ V.



(a) 3.5×10^{-4} A

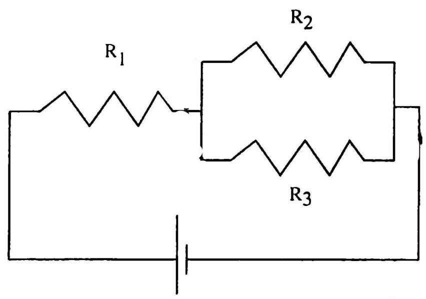
(b) 2.0×10^{-3} A

(c) 5.0×10^{-4} A

(d) zero

(e) 7.5×10^{-4} A

9. Consider the circuit shown below. The resistors are identical with $R_1 = R_2 = R_3 =$ 2.0 kΩ, and the battery voltage is $V = 9.0$ V. What is the current through resistor R_1?

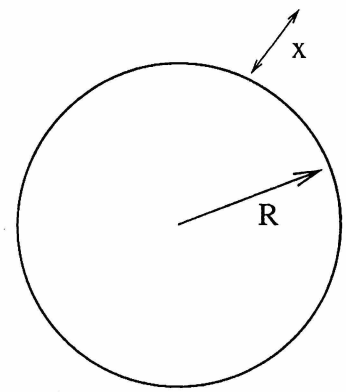


(a) 3.0×10^{-3} A
(b) 2.3×10^{-3} A
(c) 9.0×10^{-3} A
(d) 6.0×10^{-3} A
(e) 4.5×10^{-3} A

10. Suppose that three capacitors with $C_1 = 1.5$ μF, $C_2 = 1.5$ μF, and $C_3 = 3.0$ μF are connected in parallel. If the total charge on all three capacitors is 25 μC, what is the voltage across the capacitors?

(a) 8.3 V
(b) 42 V
(c) 25 V
(d) 1.2 V
(e) 4.2 V

11. A spherical metal shell has a charge per unit area σ and a radius R. What it the magnitude of the electric field at a distance x from the surface of the sphere?



(a) $k\sigma R$

(b) $k\sigma R^3/\left[R+x\right]$

(c) $4\pi k\sigma/\left[3(R+x)^2\right]$

(d) $k\sigma R^3/\left[(R+x)^2\right]$

(e) $4\pi k\sigma R^2/\left[(R+x)^2\right]$

Note: Problems 12 and 13 are both worth 6 points.

12. A 5.5 μF capacitor is connected in series with a switch, a 25 kΩ resistor and a 9 V battery. The capacitor is initially uncharged and the switch is open. The switch is then closed at $t = 0$. What is the charge on the capacitor after a very long time?

    (a) 5.5×10^{-6} C

    (b) 5.0×10^{-5} C

    (c) 9.0×10^{-5} C

    (d) zero

    (e) 2.5×10^{-5} C

13. For the $R - C$ circuit in problem 12, how long does it take after the switch is thrown until the capacitor is charged to 50% of its final value?

    (a) 0.050 s

    (b) 0.28 s

    (c) 0.069 s

    (d) 0.095 s

    (e) 0.14 s

The End

Physics 241 Exam 1
1. B
2. A
3. D
4. C
5. D
6. C
7. E
8. C
9. A
10. E
11. E
12. B
13. D