Physics 16
First Hour Exam

Name________Answer Key___________

Multiple Choice	/20
Problem 1	/32
Problem 2	/24
Problem 3	/24

Total	/100

Part I: Multiple-Choice

Circle your answer to each question. Each multiple-choice question is worth 2 points for a total of 20 points.

1. A cell membrane acts like two parallel capacitor plates. What is the potential difference across the cell membrane if it is 15 mm thick and there exists a 5 million V/m Electric field across it?

a. $3.3\text{x}10^9$ V b. $7.5\text{x}10^4$ V c. $7.5\text{x}10^7$ V d. $3.3\text{x}10^5$ V e. None of the above

$$V = Ed = (5\times10^6 \tfrac{V}{m})(15\times10^{-3}m) = 7.5\times10^4 V$$

2. A pacemaker for use in the heart has a current 0.015 A. How many electrons flow in 5 minutes?

a. $8.3\text{x}10^{19}$ b. $4.7\text{x}10^{17}$ c. $7.2\text{x}10^{-19}$ d. $1.2\text{x}10^{-20}$ e. $2.8\text{x}10^{19}$

$$I = \frac{\Delta Q}{\Delta t} \rightarrow \Delta Q = I\Delta t, \text{and } \#\text{e}^- = \frac{\Delta Q}{1.6\times10^{-19}C} = \frac{(0.015A)(300s)}{1.6\times10^{-19}C} = 2.81\times10^{19}e^-$$

3. A 10μF capacitor is used to defibrillate the heart. It is charged to 10V. What power is dissipated through the chest if the energy stored in the defibrillator is released in 10ms?

a. 0.05 W b. 0.5 W c. 5 W d. 50 W e. 500 W

$$P = \frac{\Delta E}{\Delta t} = \frac{\frac{1}{2}CV^2}{\Delta t} = \frac{\frac{1}{2}(10\times10^{-6}F)(10V)^2}{10\times10^{-3}s} = 0.05W$$

4. Which of the following quantities has units of energy?

a. FV^2 b. C^2/F c. CV d. all of the above e. none of the above.

From: ½ CV^2 $Q^2/2C$ QV

5. A proton is accelerated through a region of space where a potential difference of 12 million V exists. How fast is the proton traveling at the end of the accelerating region if it started from rest? ($M_p = 1.67\text{x}10^{-27}$ kg)

a. $5.2\text{x}10^5$ m/s b. $1.2\text{x}10^{17}$ m/s c. $2.3\text{x}10^{15}$ m/s d. $3.0\text{x}10^8$ m/s e. $4.8\text{x}10^7$ m/s

$$W = \Delta KE \rightarrow q\Delta V = \tfrac{1}{2}mV_f^2 \rightarrow V_f = \sqrt{\frac{2q\Delta V}{m}} = \sqrt{\frac{2(1.6\times10^{-19}C)(12\times10^6V)}{1.67\times10^{-27}kg}} = 4.8\times10^7 \tfrac{m}{s}$$

6. The magnitude of the electric field at a distance *r* from a source charge +*Q* is equal to E. What will the magnitude of the electric field at a distance 4*r* from a source charge +*2Q*?

a. 8E b. 2E c. E/2 d. E/4 e. E/8

$$E_{new} = \frac{k(2Q)}{(4r)^2} = \frac{1}{8}\left(\frac{kQ}{r^2}\right) = \frac{E_{old}}{8}$$

7. The electric field of a single point charge depends on which of the following:

1. the distance the observation point is from the charge.
2. the magnitude of the charge on the point charge.
3. the number of test charges used.
4. the mass of the point charge.

a. 1 and 4 b. 2, 3 and 4 c. 1 and 2 d. 2 and 4 e. 1, 2, 3, and 4

$E = \frac{kQ}{r^2}$: depends only on r and Q.

8. Suppose that a charge Q is fixed at a given location and that another charge q_o is able to move. The magnitude of the acceleration of q_o due to Q is

a. constant.
b. increasing with increasing distance between Q and q_o.
c. decreasing with increasing distance between Q and q_o.
d. depends on the acceleration due to gravity.
e. unable to be determined from the information given.

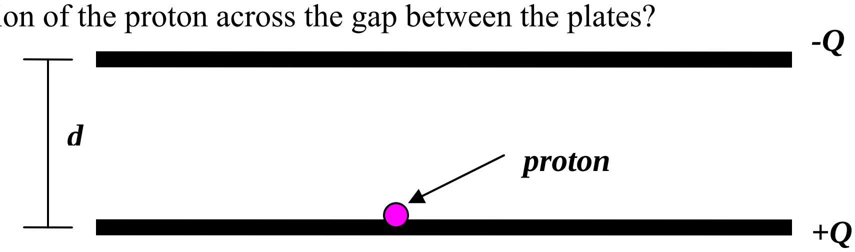
$a = \frac{F}{m} = \frac{1}{m}\left(\frac{kQq_0}{r^2}\right)$: as $r \uparrow$ then $a \downarrow$.

9. A circuit has a single battery and some resistors in it. If the equivalent resistance of the circuit halves, what happens to the total current and power dissipated by the entire circuit?

a. both increase by a factor of 4
b. both decrease by a factor of 4
c. both remain constant
d. both increase by a factor of 2
e. both decrease by a factor of 2

If the resistance halves then the current doubles. Then $P_{new} = I^2_{new}R_{new} = (2I)^2(R/2)=2I_{old}$

10. Given the parallel plate capacitor below, a proton (with mass m) is place right on top of the positively charged plate. The capacitor has charge Q on each plate, capacitance C and a uniform electric field with magnitude E between the plates. What is the acceleration of the proton across the gap between the plates?



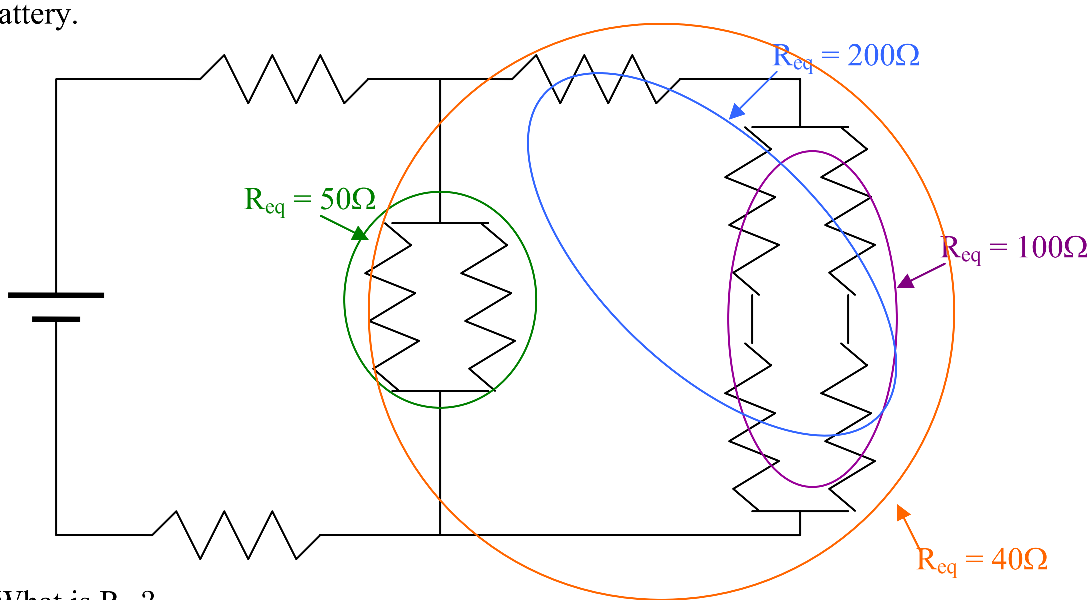
a. $a = \frac{eQ}{mCd}$ b. $a = \frac{e}{mCd}$ c. $a = \frac{Q}{md}$ d. $a = \frac{eQ}{md}$ e. none of the above

$$a = \frac{F}{m} = \frac{qE}{m} = \frac{eE}{m} = \frac{e}{m}\left(\frac{V}{d}\right) = \frac{e}{m}\left(\frac{Q}{Cd}\right)$$

Part II: Free Response Problems

Please show all work in order to receive partial credit. If your solutions are illegible no credit will be given.

1. Given the following circuit in which all resistors are 100 Ω and they are connected to a 24 V battery.



a. What is R_{eq}?

$$R_{eq} = 100\Omega + 100\ \Omega + 40\ \Omega = 240\Omega$$

b. What is I_{total} produced by the battery?

$$I_{total} = \frac{V}{R_{eq}} = \frac{24\text{V}}{240\Omega} = 0.100\text{A} = 100\text{mA}.$$

c. What is the power dissipated across the entire circuit?

$$P_{dissapated} = I^2 R_{eq} = (0.100\text{A})^2(240\Omega) = 2.40\text{W}$$

$$P_{dissapated} = \frac{V^2}{R_{eq}} = \frac{(24\text{V})^2}{240\Omega} = 2.40\text{W}$$

$$\text{P}_{\text{dissapated}} = IV = (0.100A)(24V) = 2.40\text{W}$$

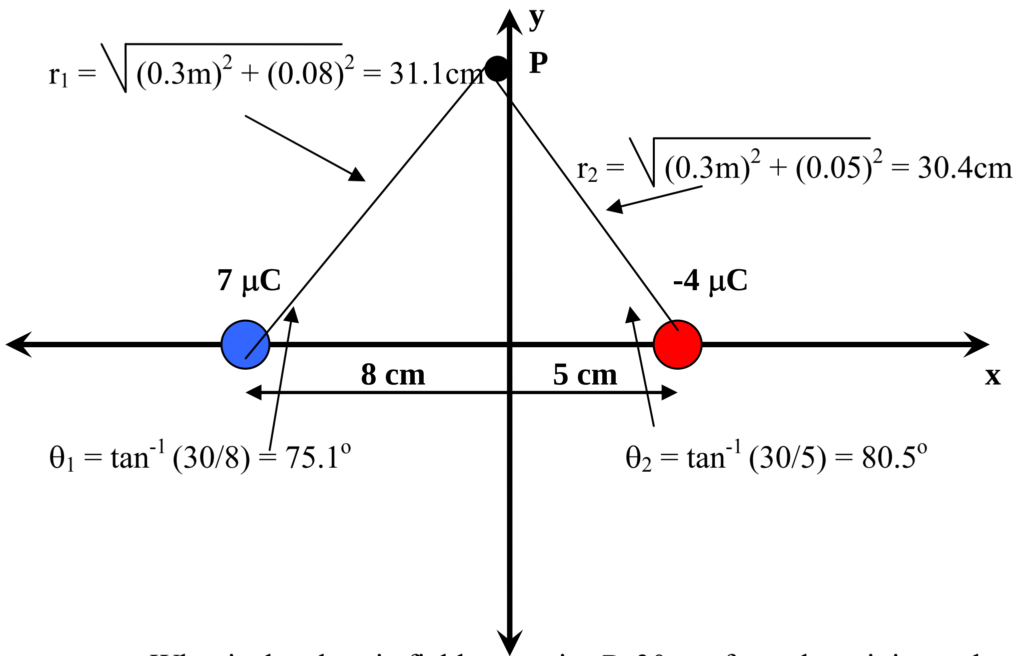
d. If these resistors were replaced by their equivalent resistance (calculated in *part a*), and then connected to a charged 60,000 μF isolated capacitor, how long would it take for 63% of the charge to leave the capacitor through the resistor?

Since, $Q = Q_0 e^{\frac{-t}{RC}}$, 63% dissapated means $Q = 0.37Q_0$.

Solving for t, we find $t = RC$.

$$\tau = R_{eq}C = (240\Omega)(60{,}000 \times 10^{-6}\,\text{F}) = 14.4\text{s}$$

2. Consider the arrangement of charges shown below.



a. What is the electric field at a point ***P***, 30 cm from the origin on the y-axis? (Hint: Remember that the electric field is a vector quantity.)

$$E_{net,x} = E_7 \cos\theta_1 + E_4 \cos\theta_2 = k\frac{Q_7}{r_1^2}\cos\theta_1 + k\frac{Q_4}{r_2^2}\cos\theta_2$$

$$E_{net,y} = 2.31\times10^5 \ \tfrac{\mathrm{N}}{\mathrm{C}}$$

$$E_{net,y} = E_7 \sin\theta_1 - E_4 \sin\theta_2 = k\frac{Q_7}{r_1^2}\sin\theta_1 - k\frac{Q_4}{r_2^2}\sin\theta_2$$

$$E_{net,y} = 2.45\times10^5 \ \tfrac{\mathrm{N}}{\mathrm{C}}$$

$$\therefore E_{net} = \sqrt{E_{net,x}^2 + E_{net,y}^2} \ @\ \theta = \tan^{-1}\left(\frac{E_{net,y}}{E_{net,y}}\right)$$

$$E_{net} = 3.37\times10^5 \ \tfrac{\mathrm{N}}{\mathrm{C}} \ @\ \theta = 46.7^0 \ \text{above x} - \text{axis.}$$

b. What is the electric potential at point ***P***?

$$V_{total} = V_7 + V_4 = k\frac{Q_7}{r_1} - k\frac{Q_4}{r_2}$$

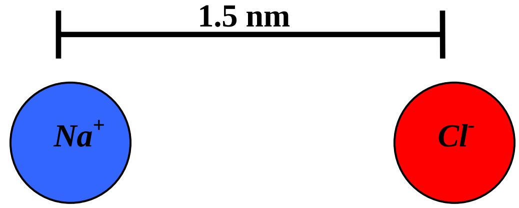
$$V_{total} = 8.37\times10^4\ \mathrm{V}$$

c. How much work is required to bring in a 2 μC charge from ***infinity*** to ***P*** along the y-axis?

$$W_{total} = q\Delta V_P = q\left(V_{\text{infinity}} - V_P\right) = 2\times10^{-6}\ \mathrm{C}\left(0 - 8.37\times10^4\ \mathrm{V}\right)$$

$$W_{total} = -0.17\mathrm{J}$$

3. Consider the electric dipole as shown below. The charge of the sodium ion is +1e$^-$ and the charge on the chlorine ion is -1e$^-$ and their separation is 1.5 nm (1 nm is 1x10^{-9} m).



a. What is the electrostatic force on the Na$^+$ ion due to the Cl$^-$ ion? (Hint: The electrostatic force is a vector quantity.)

$$F_{Na^+,Cl^-} = k\frac{q_{Na^+}q_{Cl^-}}{r^2} = \left(9\times10^9\ \tfrac{\text{Nm}^2}{\text{C}^2}\right)\frac{\left(1.6\times10^{-19}\,\text{C}\right)^2}{\left(1.5\times10^{-9}\,\text{m}\right)^2}$$

$$F_{Na^+,Cl^-} = 1.02\times10^{-10}\,\text{N directed toward the chlorine ion.}$$

b. How much work does it take to assemble this dipole if each charge is brought in from infinity to their present separation?

$$W_{Na^+} = 0J$$

$$W_{Cl^-} = q_{Cl^-}\left(0 - k\frac{q_{Na^+}}{r}\right) = \left(-1.6\times10^{-19}\right)\text{C}\left(0 - \left(9\times10^9\ \tfrac{\text{Nm}^2}{\text{C}^2}\right)\frac{\left(1.6\times10^{-19}\,\text{C}\right)}{\left(1.5\times10^{-9}\,\text{m}\right)}\right)$$

$$= 1.54\times10^{-19}\,\text{J}$$

$$W_{total} = W_{Na^+} + W_{Cl^-} = 1.54\times10^{-19}\,\text{J}$$

c. Since the work done equals the negative change in the potential energy, how much potential energy is stored in this system? (Comment: The answer you get may surprise you. This system forms an ionic bond and it is therefore a bound system as your answer does indicate. We'll comment more on this in class.)

$$W_{total} = -\Delta PE = -1.54\times10^{-19}\,\text{J}$$

$$W_{total} = -\Delta PE = -1.54\times10^{-19}\,\text{J}\times\frac{1\text{eV}}{1.6\times10^{-19}\,\text{J}} = -0.96\text{eV}$$