Physics 212 / Summer 2008 Name: ANSWER KEY

Dr. Zimmerman

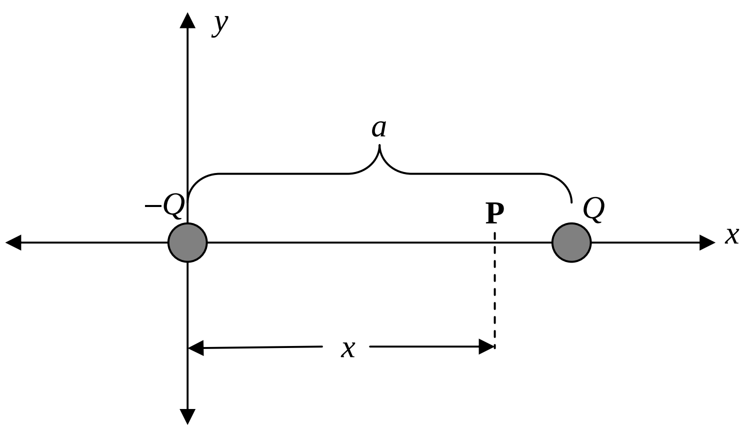
Exam 2

Material Covered: Chapters 29 – 32.4 in *Physics for Scientists & Engineers with Modern Physics (1/e)* by Randall Knight.

Problem	Score/Possible
(1)	/ 25
(2)	/ 25
(3)	/ 25
(4)	/ 25
Total →	/ 100

Show all your work.
Exam is closed book.
Partial Credit will be given.
You may use a calculator.
Please don't cheat.

(1) In the charge configuration shown below, a charge $-Q$ is located at the origin and a charge $+Q$ is located at $x = a$. (a) Calculate the electric potential, $V(x)$, at the point **P**, located at $x < a$. (b) Show that the value of the electric potential at the midpoint between the charges is exactly zero. (c) Find the *electric field* at the point **P** by taking appropriate derivatives of the electric potential $V(x)$ that you found in part (a). (d) What is the electric field at the midpoint between the charges? (e) How can the potential at a midpoint between charges be zero while the electric field is not?



(a) $V(x) = \boxed{\frac{Q}{4\pi\varepsilon_0}\left(\frac{-1}{x} + \frac{1}{a-x}\right)}$

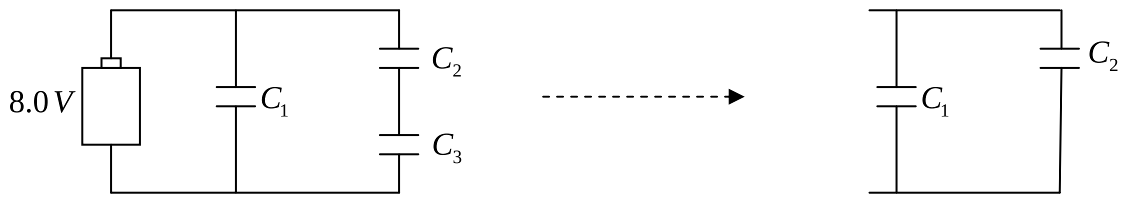
(b) $V(a/2) = \frac{Q}{4\pi\varepsilon_0}\left(\frac{-1}{a/2} + \frac{1}{a/2}\right) = \boxed{0}$

(c) $E_x = \frac{-dV}{dx} = \boxed{-\left[\frac{Q}{4\pi\varepsilon_0 x^2} + \frac{Q}{4\pi\varepsilon_0 (a-x)^2}\right]}$

(d) $E_x(a/2) = -\frac{Q}{4\pi\varepsilon_0 (a^2/4)} - \frac{Q}{4\pi\varepsilon_0 (a^2/4)} = \boxed{\frac{-2Q}{\pi\varepsilon_0 a^2}}$

(e) *The potential is a scalar and goes from a negative number to a positive number through the midpoint – thus passing through zero. The electric field is a vector and the fields both point to the left between the charges and thus do not cancel.*

(2) The capacitor circuit shown is charged using a 8V battery. (a) If $C_1 = 10\ \mu F$, $C_2 = 5.0\ \mu F$, and $C_3 = 5.0\ \mu F$, determine the charge on each capacitor. (b) The battery is then removed, leaving the same charge on each capacitor. However, now capacitor C_3 is removed along with its charge. It is replaced with a wire, allowing charge to redistribute as C_1 and C_2 are now in parallel. What is the charge on the remaining two capacitors? (c) What is the voltage across each now?



(a) Equivalent capacitance $C_{23} = (1/C_2 + 1/C_3)^{-1} = 2.5\ \mu F$. Then voltage across each is the same so we can find the charge,

$$Q_1 = (10\ \mu F)(8.0\ V) = \boxed{80\ \mu C};\ Q_2 = Q_3 = (2.5\ \mu F)(8.0\ V) = \boxed{20\ \mu C}$$

(b) Charge will flow until the voltage is the same – after all, they are in parallel. The total charge will remain constant, $Q_1 + Q_2 = 100\ \mu C$. The voltage across each is,

$$\Delta V_1 = Q_1 / C_1 \text{ and } \Delta V_2 = Q_2 / C_2$$

Since these are equal we have,

$$\frac{Q_1}{C_1} = \frac{100 - Q_1}{C_2}$$

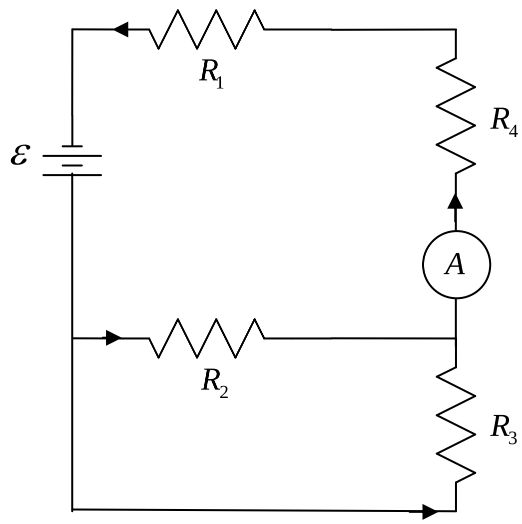
$$Q_1 C_2 = 100 C_1 - Q_1 C_1$$

$$Q_1 = \frac{100 C_1}{C_1 + C_2} = \boxed{66.7\ \mu C}$$

$$Q_2 = 100\ \mu C - Q_1 = \boxed{33.3\ \mu C}$$

(c) $\Delta V_1 = \frac{Q_1}{C_1} = \frac{66.7}{10} = \boxed{6.67\ V}; \Delta V_2 = \frac{Q_1}{C_1} = \frac{33.3}{5} = \boxed{6.67\ V}$; {they are the same of course!}

(3) In the circuit below, a perfect ammeter reads a current of $I_4 = 2.0A$ up the page. All the resistors have the same value: $R_1 = R_2 = R_3 = R_4 = 1.0\,\Omega$. (a) Determine the currents in all the other resistors (I_1, I_2, I_3). (b) Find the voltage of the battery, $\mathcal{E}$.



(a) We know $I_4 = 2.0A$

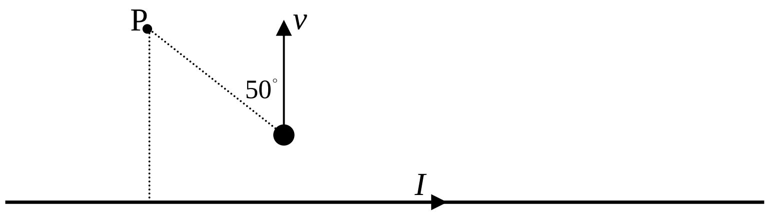
R_1 and R_4 are in series, so the current is the same through them. Thus, we know the current through R_1: $I_1 = \boxed{2.0\ A}$.

Now R_2 and R_3 are in parallel. Since they have the same resistance, the current will be divided since the voltage is the same across them: $I_2 = I_3 = \boxed{1.0\ A}$

(b) Now we can use the loop rule to determine ε. Going CCW in the top loop we have,

$$\varepsilon - I_2R_2 - I_4R_4 - I_1R_1 = 0$$
$$\varepsilon = 1.0\,V + 2.0\,V + 2.0\,V = \boxed{5.0\,V}$$

(4) A charge $q = 10\ \mu C$ moves with speed $v = 3.0 \times 10^4\ m/s$ near a very long straight wire carrying a current $I = 10\ A$ as shown. Using the principle of superposition, determine the magnetic field at the point P due to the wire and the moving proton. The point P is $5.0\ cm$ from the proton and $7.0\ cm$ (perpendicularly) from the wire.



$$\vec{B}_{proton} = \frac{\mu_0 q v \sin\theta}{4\pi r^2} = 9.2\ \mu T \ \text{\{out of the page\}}$$

$$\vec{B}_{wire} = \frac{\mu_0 I}{2\pi d} = 28.6\ \mu T \ \text{\{out of the page\}}$$

$$\vec{B}_{total} = \vec{B}_{charge} + \vec{B}_{wire} = \boxed{37.8\ \mu T} \ \text{\{out of the page\}}$$