Name________________________

Feb. 21, 2002

Phys 2020 — Spring 2002
Exam #1

1.	________________	(8)
2.	________________	(9)
3.	________________	(22)
4.	________________	(11)
5.	________________	(16)
6.	________________	(14)
MC	________________	(20)
Total	________________	(100)

$$v_x = v_{0x} + a_x t \qquad v_y = v_{0y} + a_y t \qquad x = x_0 + v_{0x}t + \tfrac{1}{2}a_x t^2 \qquad y = y_0 + v_{0y}t + \tfrac{1}{2}a_y t^2$$

$$k = \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \,\tfrac{\mathrm{N\cdot m^2}}{\mathrm{C^2}} \qquad \epsilon_0 = 8.85 \times 10^{-12}\,\tfrac{\mathrm{C^2}}{\mathrm{N\cdot m^2}} \qquad F = k\frac{|q_1 q_2|}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{|q_1 q_2|}{r^2}$$

$$\mathbf{F} = m\mathbf{a} \qquad g = 9.80\,\tfrac{\mathrm{m}}{\mathrm{s^2}} \qquad m_{\mathrm{elec}} = 9.1094 \times 10^{-31}\,\mathrm{kg} \qquad e = 1.602 \times 10^{-19}\,\mathrm{C}$$

$$\mathbf{F} = q\mathbf{E} \qquad E_{\mathrm{pt\ ch}} = k\frac{|q|}{r^2} \qquad E_{\mathrm{p-plates}} = \frac{\sigma}{\epsilon_0} \qquad \Delta\mathrm{EPE} = q\Delta V \qquad V_{\mathrm{pt\ ch}} = k\frac{q}{r} \qquad E_x = -\frac{\Delta V}{\Delta x}$$

$$A_{\mathrm{circ}} = \pi R^2 \qquad Q = CV \qquad E = \tfrac{1}{2}CV^2 \qquad C_{\mathrm{p-plates}} = \epsilon_0\frac{A}{d} \qquad I = \frac{\Delta q}{\Delta t}$$

$$V = IR \qquad R = \rho\frac{L}{A} \qquad P = IV = I^2R \qquad R_{\mathrm{ser}} = R_1 + R_2 + \dots \qquad \frac{1}{R_{\mathrm{par}}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$$

$$F = qvB\sin\theta\ \text{, w/ RHR-1} \qquad F = ILB\sin\theta \qquad \tau = NIAB\sin\phi = mB\sin\phi$$

$$r = \frac{mv}{qB} \qquad \mathrm{KE} = \tfrac{1}{2}mv^2 \qquad \mu_0 = 4\pi \times 10^{-7}\,\tfrac{\mathrm{T\cdot m}}{\mathrm{A}} \qquad B_{\infty\ \mathrm{wire}} = \frac{\mu_0 I}{2\pi r}$$

Multiple Choice

1. Under electrostatic conditions, the electric field inside of a conductor is:

a) Zero.

b) Non-zero, but uniform (same value everywhere).

c) Non-uniform and largest near the surface.

d) Non-uniform and smaller near the surface.

2. Two point charges Q_A and Q_B lie along a line separated by a distance L. What combination of charges would yield the greatest repulsive force between the charges?

a) $Q_A = -2q$ and $Q_B = -4q$

b) $Q_A = +3q$ and $Q_B = +3q$

c) $Q_A = +q$ and $Q_B = +7q$

d) $Q_A = -q$ and $Q_B = -8q$

3. For the configuration of charges shown at the right, there is (?) a point where the electric field is zero. It is:

a) To the left of Q_A.

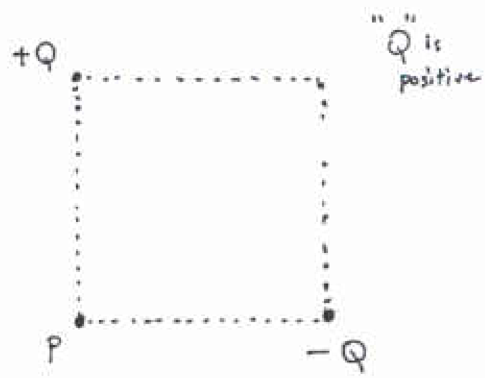
b) To the right of Q_B.

c) Between Q_A and Q_B.

d) Nowhere.

4. The figure at the right shows two particles with charges $+Q$ and $-Q$, located at the opposite corners of a square of side d.

What is the direction of the net electric field at point P?



a) 

b) 

c) 

d) 

5. (Continuing with the charges in Problem 4): What is the potential energy of a particle of charge q that is held at point P?

a) $U = 2k\frac{qQ}{d}$

b) $U = \sqrt{2}k\frac{qQ}{d}$

c) $U = -2k\frac{qQ}{d}$

d) $U = 0$

6. A Farad is equal to

a) $1\,\frac{A}{N}$

b) $1\,\frac{J}{C}$

c) $1\,\frac{C}{V}$

d) $1\,\frac{C}{N}$

7. A current of 10.0 A flows through a 100 Ω resistor. How much energy is dissipated in the resistor in 1 minute?

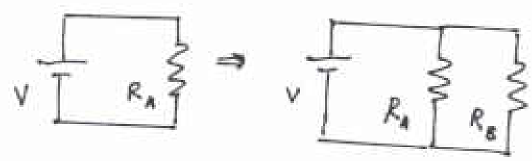
a) 6.0×10^2 J

b) 6.0×10^3 J

c) 6.0×10^4 J

d) 6.0×10^5 J

8. A battery is attached across the leads of resistor R_A. When another resistor R_B is added to the circuit, in parallel with R_A, the current through R_A will:



a) Decrease.

b) Increase.

c) Stay the same.

d) Decrease or increase depending on the values of R_A and R_B.

9. Wires A and B are made out of the same material and have the same length but when comparing their circular cross-sections, wire B has twice the radius of wire A. The resistance of wire B as compared with A is

a) $\frac{1}{4}$ times as large.

b) $\frac{1}{2}$ times as large.

c) 2 times as large.

d) 4 times as large.

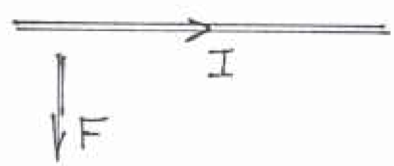
10. On the wire illustrated here the current flows to the right. A magnetic field gives a downward force on the wire. The direction of the magnetic field is

a) Out of the page.

b) Into the page.

c) Downward.

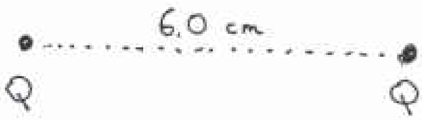
d) Upward.



Problems

1. Two identical charges are separated by a distance of 6.0 cm experience a repulsive force of magnitude 0.55 N. What is the charge of each particle? (Be complete... there are *two* answers to the problem! (8)

With $r = 6.0\text{ cm}$, Coulomb's law gives



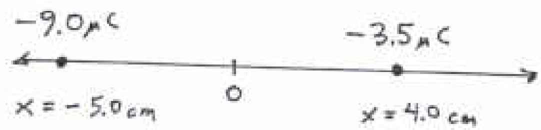
$$k\frac{Q^2}{r^2} = (0.55\,N)$$

$$Q^2 = \frac{(0.55\,N)\,r^2}{k} = \frac{(0.55\,N)(0.060\,m)^2}{(8.99\times10^9\,\frac{Nm^2}{C^2})} = 2.20\times10^{-13}\,C^2$$

$$Q = \boxed{+4.69\times10^{-7}\,C \quad \text{or} \quad -4.69\times10^{-7}\,C}$$

2. Two point charges are on the x–axis. A $-3.5\,\mu$C charge is at $x = 4.0$ cm and a $-9.0\,\mu$C charge is at $x = -5.0$ cm.

Find the magnitude and direction of the electric field at the origin. (9)



Field due to left charge points in $-x$ direction, so it contributes:

$$E_x = -k\frac{q_1}{r_1^2} = -(8.99\times10^9\,\frac{Nm^2}{C^2})\frac{(9.0\times10^{-6}C)}{(0.050\,m)^2} = -3.24\times10^7\,\frac{N}{C}$$

Field due to right charge points in $+x$ direction so it contributes:

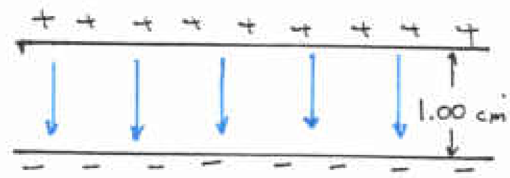
$$E_x = +k\frac{q_2}{r_2^2} = +(8.99\times10^9\,\frac{Nm^2}{C^2})\frac{(3.5\times10^{-6}C)}{(0.040\,m)^2} = +1.97\times10^7\,\frac{N}{C}$$

Total is

$$E_{x,\,total} = \boxed{-1.27\times10^7\,\frac{N}{C}}$$

i.e. it has magnitude $\boxed{1.27\times10^7\,\frac{N}{C}}$ and points to the **left**

3. Shown at the right is a side view of two parallel plates which are large compared to their separation and which carry opposite charges whose signs are indicated. The plates are separated by 1.00 cm.



When a potential difference V is applied the resulting (uniform) $\mathbf{E}$ field has magnitude 800. $\frac{\text{N}}{\text{C}}$.

a) On the diagram, show the direction of the $\mathbf{E}$ field. (2)

Direction is as shown; $\vec{E}$ field points from + to − charges.

b) What is the magnitude of the potential difference between the plates? (3)

$\vec{E}$ field is uniform so we can use:

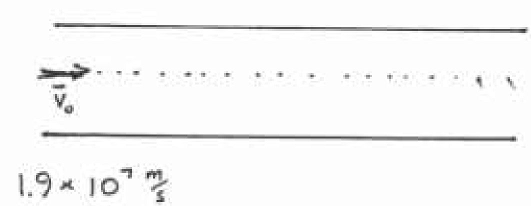
$$|\Delta V| = E_x \Delta x = \left(800 \tfrac{V}{m}\right)(0.0100\,m) = \boxed{8.00\ V}$$

c) What is surface charge density of either one of the plates? (4)

Use $E_{p\text{-}pl} = \sigma/\epsilon_0$, then

$$\sigma = E_x \epsilon_0 = \left(800 \tfrac{N}{C}\right)\left(8.85 \times 10^{-12} \tfrac{C^2}{Nm^2}\right) = \boxed{7.08 \times 10^{-9}\ C/m^2}$$

d) Electrons are in injected between the plates with an initial horizontal velocity and speed $1.9 \times 10^7\ \frac{\text{m}}{\text{s}}$. What is magnitude and direction of the force on the electrons? (4)



Magnitude of the force is

$$|\vec{F}| = |q\vec{E}| = (1.602 \times 10^{-19} c)\left(800 \tfrac{N}{C}\right)$$
$$= \boxed{1.28 \times 10^{-16}\ N}$$

Direction is opposite the dir. of $\vec{E}$ since charge is negative. Hence, force is $\boxed{\text{up.}}$

e) What is the magnitude and direction of the acceleration of the electrons? (4)

Acceleration has magnitude

$$a = F/m = \frac{(1.28 \times 10^{-16} N)}{(9.11 \times 10^{-31} kg)} = \boxed{1.41 \times 10^{14}\ \tfrac{m}{s^2}}$$

Direction is the same as that of $\vec{F}$, namely $\boxed{\text{up.}}$

f) How long does it take the electrons to travel a horizontal distance of 10.0 cm between the plates? (2)

Use $x = v_{0x} t$ (no x-acceleration!) with $v_{0x} = 1.9 \times 10^{7}\ \frac{m}{s}$

then:
$$t = \frac{x}{v_{0x}} = \frac{(0.100\ m)}{(1.9 \times 10^{7}\ \frac{m}{s})} = \boxed{5.3 \times 10^{-9}\ s}$$

g) When the electrons have travelled this horizontal distance, what is the magnitude and direction of their vertical displacement? (3)

At the time found in (f) the y-coordinate is
$$y = 0 + \frac{1}{2} a_y t^2 = \frac{1}{2}(1.41 \times 10^{14}\ \frac{m}{s^2})(5.3 \times 10^{-9}\ s)^2 = \boxed{1.9 \times 10^{-3}\ m = 1.9\ mm}$$

4. A point charge $Q = +4.0\,\mu C$ is fixed at the origin.

a) What is the value of the electric potential at $x = 10.0$ cm? (4)

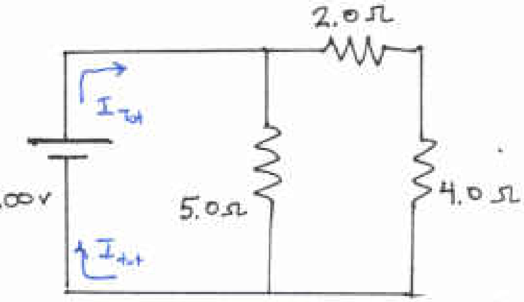
Using $V_{pt-ch} = k\frac{q}{r}$ (this really assumes $V = 0$ at $r = \infty$!) get:
$$V_{10} = k\frac{q}{r} = (8.99 \times 10^{9}\ \frac{N m^2}{C^2})\frac{(4.0 \times 10^{-6}\ C)}{(0.100\ m)} = \boxed{3.6 \times 10^{5}\ V}$$

b) How much work is required to move a charge $q = +1.0\,\mu C$ from $x = 10.0$ cm to $x = 5.0$ cm? (7)

The potential at $x = 5.0$ cm is
$$V_5 = k\frac{q}{r} = (8.99 \times 10^{9}\ \frac{N m^2}{C^2})\frac{(4.00 \times 10^{-6}\ C)}{(0.050\ m)} = 7.2 \times 10^{5}\ V$$

The work required to move the charge is the change in EPE, namely $q\Delta V$:
$$W = q\Delta V = (1.0 \times 10^{-6}\ C)(7.2 \times 10^{5}\ V - 3.6 \times 10^{5}\ V)$$
$$= \boxed{0.36\ J}$$

5. A 9.00 − V battery is connected to the combination of resistors show at the right.



a) Find the *total* current in the circuit. (5)

Equivalent resistance of the combination is:

2.0 Ω, 4.0 Ω in series → 6.0 Ω

6.0 Ω in parallel with 5.0 Ω : $\frac{1}{R_{eq}} = \frac{1}{5.0\,\Omega} + \frac{1}{6.0\,\Omega}$

$R_{eq} = 2.73\,\Omega$ Then: $I_{Tot} = \frac{V}{R_{eq}} = \frac{9.00\text{ V}}{2.73\,\Omega} = \boxed{3.3\text{ A}}$

b) What is the voltage drop across the 5.0 − Ω resistor? (2)

9.00 V battery is connected across its ends! By Kirchhoff Loop Rule, voltage drop must be $\boxed{9.00\text{ V}}$

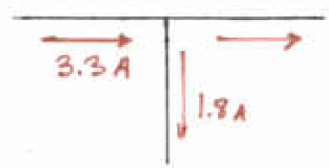
c) What is the current in the 5.0 − Ω resistor? (3)

Can now use Ohm's Law for 5.0 Ω resistor. Get:

$$I_{5\Omega} = \frac{V_{5\Omega}}{R} = \frac{(9.00\text{ V})}{(5.0\,\Omega)} = \boxed{1.8\text{ A}}$$

d) What is the current in the 2.0 − Ω resistor? (3)

Using the Kirchhoff Junction rule and the answers to (a) and (c) the current through the 2 Ω (and 4 Ω) resistor must be



$$I_{2\Omega} = 3.3\text{ A} - 1.8\text{ A} = \boxed{1.5\text{ A}}$$

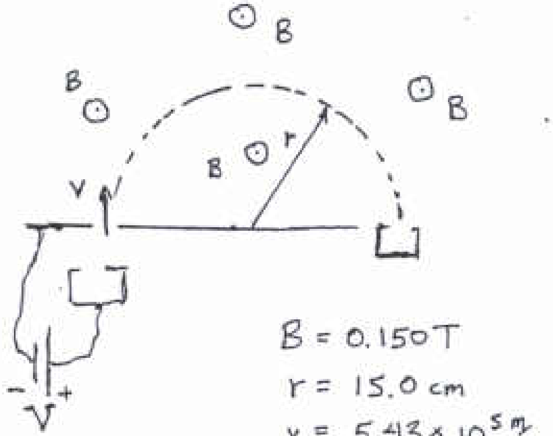
e) What is the power dissipated in the 4.0 − Ω resistor? (3)

Since 1.5 A also passes through the 4 Ω resistor, the power dissipated in it is

$$P = I_4^2 R = (1.5\text{ A})^2(4.0\,\Omega) = \boxed{9.0\text{ W}}$$

6. In the mass analyzer diagrammed at the right, a singly-charged ($+e$) ion is accelerated from rest through a potential difference V and then enters a region where it moves in a plane perpendicular to a uniform magnetic field of strength $B = 0.150\,\mathrm{T}$. The field makes the ions move in a circular path.

When the ions enter the region their speed is $5.43 \times 10^5\ \frac{\mathrm{m}}{\mathrm{s}}$ and they are detected at a radius of 15.0 cm.



$B = 0.150\,\mathrm{T}$

$r = 15.0\ \mathrm{cm}$

$v = 5.43 \times 10^5\ \frac{m}{s}$

a) What is the mass of the ions? (8)

Use the relation for circ. motion in a $\vec{B}$ field,

$r = \frac{mv}{qB}$. Then:

$$m = \frac{qBr}{v} = \frac{(1.602\times10^{-19}\,C)(0.150\,T)(0.150\,m)}{(5.43\times10^5\ \frac{m}{s})} = \boxed{6.64\times10^{-27}\ kg}$$

b) What is the kinetic energy of the ions after the are accelerated through the potential V? (2)

$$KE = \tfrac{1}{2}mv^2 = \tfrac{1}{2}(6.64\times10^{-27}\,kg)(5.43\times10^5\ \tfrac{m}{s})^2 = \boxed{9.79\times10^{-16}\ J}$$

c) What is the potential V through which the ions were accelerated. (4)

The KE is equal to the change in potential energy as they are accelerated.

So $KE = qV$, or:

$$V = \frac{(KE)}{q} = \frac{(9.79\times10^{-16}\,J)}{(1.602\times10^{-19}\,c)} = \boxed{6.1\times10^3\ V = 6.1\ kV}$$