Name________________________

Sept. 24, 2002

Phys 2020 — Fall 2002

Exam #1

1.	__________	(8)
2.	__________	(10)
3.	__________	(4)
4.	__________	(8)
5.	__________	(17)
6.	__________	(18)
7.	__________	(11)
8.	__________	(4)
MC	__________	(20)
Total	__________	(100)

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

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

$$\mathbf{F} = q\mathbf{E} \qquad E_{\text{pt ch}} = k\frac{|q|}{r^2} \qquad E_{\text{plates}} = \frac{q}{\epsilon_0 A} = \frac{\sigma}{\epsilon_0} \qquad \Delta\text{EPE} = q\Delta V \qquad V_{\text{pt ch}} = k\frac{q}{r}$$

$$|E_x| = \left|\frac{\Delta V}{\Delta x}\right| \qquad q = CV \qquad C = \frac{\epsilon_0 A}{d} \qquad \text{Energy} = \tfrac{1}{2}CV^2$$

$A_{cir} = \pi r^2$

$$V = IR \qquad R_{\text{ser}} = R_1 + R_2 + \dots \qquad \frac{1}{R_{\text{par}}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$$

$R = \rho \frac{L}{A}$

$$P = VI = I^2R = \frac{V^2}{R} \qquad \text{Energy} = Pt \qquad F = qvB\sin\theta$$

Multiple Choice

Choose the best answer from among the four!

1. Charges Q_1 and Q_2 each feel a repulsive for F when they are separated by a distance R. What is the repulsive force when they are separated by a distance $R/3$?

   a) $F/3$

   b) F

   c) $3F$

   d) $9F$

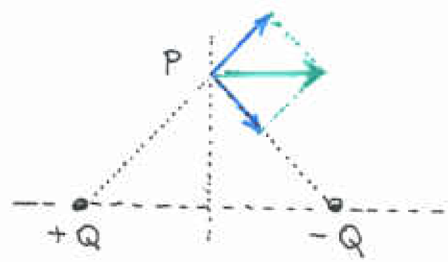
2. A configuration with two charges, $+Q$ and $-Q$ is shown at the right. The net electric field at point P points in the direction given by:

   a) ↑

   b) ↓

   c) →

   d) ←



3. The value of an electric field can be expressed in:

   a) Ohm-m

   b) Volts/m

   c) Microfarads.

   d) Coulomb/s

4. The electric potential is

   a) Energy per charge.

   b) Force per charge.

   c) Force per unit of current.

   d) Charge per unit of force.

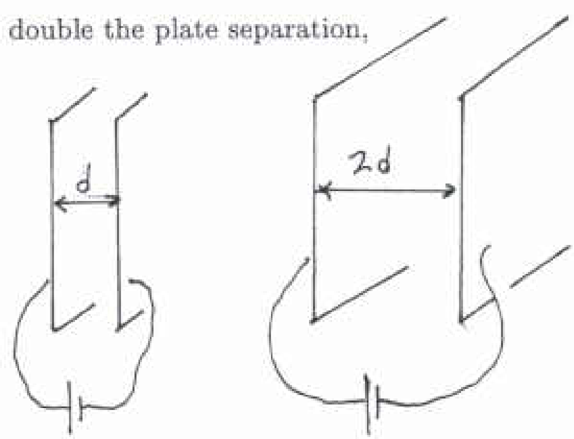
5. A parallel plate capacitor is connected to a battery. If we double the plate separation,

   a) The potential difference is halved.

   b) The capacitance is doubled.

   c) The charge on each plate is halved.

   d) The electric field is doubled.



6. A and B are two cylindrical resistors with circular cross-section and made of the same material. Resistor B is 4 times the length A and has a radius twice as big. If A has resistance R_A, then B has resistance.

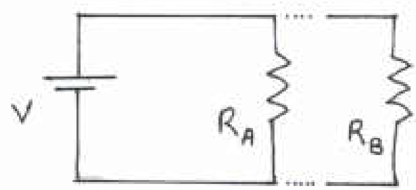
a) $R_A/2$

b) R_A

c) $4R_A$

d) $8R_A$

7. A resistor R_A is connected to a battery V. If resistor B is added to the circuit as shown, the current through R_A will



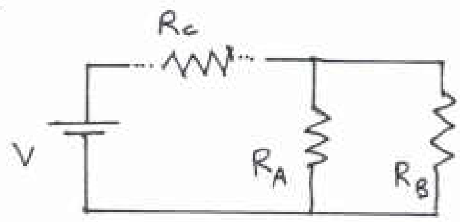
a) Decrease.

b) Increase.

c) Stay the same.

d) Can increase or decrease depending on the value of R_B.

8. Another resistor, R_C, is added to the circuit as shown. Adding R_C will now make the current through R_A



a) Decrease.

b) Increase.

c) Stay the same.

d) Can increase or decrease depending on the value of R_C.

9. The unit of magnetic field is the

a) Henry

b) Ampere

c) Weber

d) Tesla.

10. A charged particle will experience a magnetic force when it...

a) Is moving in the same direction as the magnetic field.

b) Is moving in the opposite direction as the magnetic field.

c) Is moving perpendicular to the direction of the magnetic field.

d) Has zero velocity.

Problems

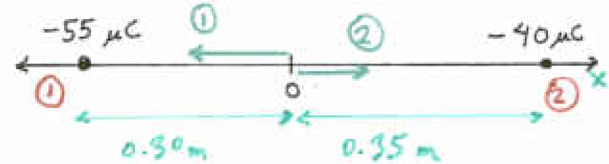
1. Two identical charges of $5.0\,\mu C$ experience a force of repulsion of magnitude $2.00\,N$. By what distance are the charges separated? (8)

Let unknown distance be r. Coulomb's law sez $F = k\frac{Q^2}{r^2}$ (since the charges are the same). Solve for r, get:

$$r^2 = \frac{kQ^2}{F} = \frac{(8.99\times 10^9)(5.0\times 10^{-6})^2}{(2.00)}\,m^2 = 0.112\ m^2$$

$$\rightarrow\ r = \sqrt{0.112\,m^2} = 0.335\ m = \boxed{33.5\ cm}$$

2. Two point charges are located on the x axis: A $-55\,\mu C$ charge is located at $x = -30\,cm$, and a $-40\,\mu C$ charge is located at $x = +35\,cm$.



Find the magnitude and direction of the electric field at the origin ($x = 0\,cm$). (10)

Magnitude of electric field due to charge ①: Using $E = k\frac{|q|}{r^2}$, get:

$$E_1 = \left(8.99\times 10\ \frac{N\cdot m^2}{C^2}\right)\frac{(55\times 10^{-6}\,C)}{(0.30\,m)^2} = 5.49\times 10^6\ N/C$$

Goes in $-x$ direction!

Magnitude of electric field due to charge ②:

$$E_2 = \left(8.99\times 10^9\ \frac{Nm^2}{C^2}\right)\frac{(40\times 10^{-6}\,C)}{(0.35\,m)^2} = 2.94\times 10^6\ \frac{N}{C}$$

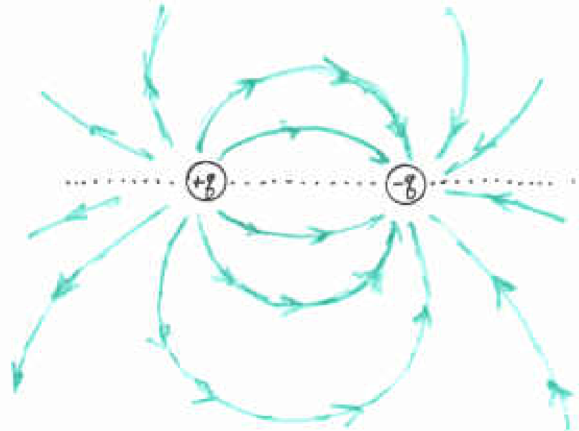
Goes in $+x$ direction!

Then the x-component of total E-field at the origin is:

$$E_x = -5.49\times 10^6\ N/C + 2.94\times 10^6\ N/C = -2.56\times 10^6\ N/C$$

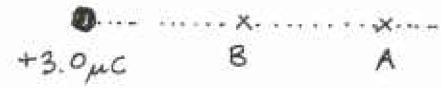
So it has magnitude $\boxed{2.56\times 10^6\ \frac{N}{C}}$ and points in the $\boxed{-x}$ direction.

3. At the right are shown two charges of equal magnitude but opposite sign... a *electric dipole*. Sketch in a few representative field lines, showing their directions. (4)



4. Point A is 10.0 cm from a $+3.0\,\mu$C charge. Point B is 5.0 cm from the charge.

a) Find the electric potential at point A and at point B. (4)



Using $V_{pt\text{-}ch} = k\frac{q}{r}$, get:

$$V_A = (8.99\times10^9)\frac{(3.0\times10^{-6})}{(0.100)}\ \text{V} = \boxed{2.70\times10^5\ \text{V}}$$

$$V_B = (8.99\times10^9)\frac{(3.0\times10^{-6})}{(0.050)}\ \text{V} = \boxed{5.39\times10^5\ \text{V}}$$

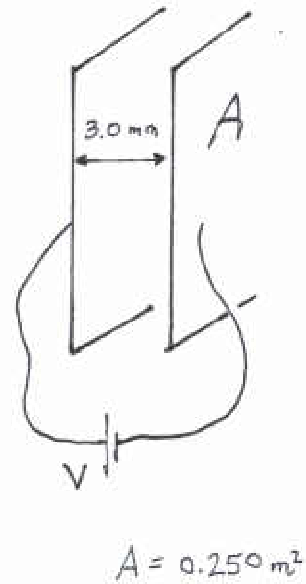
b) Find the work required to move a $+6.0\,\mu$C charge from A to B. (4)

Work req'd is equal to change in Elec. Pot. Energy:

$$\Delta EPE = q\,\Delta V = q(V_B - V_A)$$

$$= (6.0\times10^{-6}\,\text{C})(5.39\times10^5\,\text{V} - 2.70\times10^5\,\text{V}) = \boxed{1.62\ \text{J}}$$

5. A capacitor is formed from two large parallel plates of area $0.250\,\mathrm{m}^2$ separated by $3.0\,\mathrm{mm}$. A voltage V is applied to the plates and a charge $\pm 3.0\,\mu\mathrm{C}$ is stored on the plates.



a) Find the charge density σ on the plates.(3)

By the definition,

$$\sigma = \frac{q}{A} = \frac{(3.0\times10^{-6}\,\mathrm{C})}{(0.250\,\mathrm{m}^2)} = \boxed{1.2\times10^{-5}\,\frac{\mathrm{C}}{\mathrm{m}^2}}$$

b) Find the magnitude of the electric field between the plates. (4)

Between opp ch'd par. plates $E = \sigma/\epsilon_0$ so

$$E = \frac{\sigma}{\epsilon_0} = \frac{(1.2\times10^{-5}\,\mathrm{C/m^2})}{(8.85\times10^{-12}\,\frac{\mathrm{C^2}}{\mathrm{Nm^2}})} = \boxed{1.36\times10^{6}\,\frac{\mathrm{N}}{\mathrm{C}}}$$

c) Find the applied voltage V. (3)

Magnitude of the applied potential difference is $|\Delta V| = |E\,\Delta x|$, so

$$\text{"}V\text{"} = \Delta V = (1.36\times10^{6}\,\tfrac{\mathrm{V}}{\mathrm{m}})(3.0\times10^{-3}\,\mathrm{m}) = \boxed{4.1\times10^{3}\,\mathrm{V}}$$

d) Find the capacitance C (4)

C, q and V related by $q = CV$, so

$$C = \frac{q}{V} = \frac{(3.0\times10^{-6}\,\mathrm{C})}{(4.1\times10^{3}\,\mathrm{V})} = \boxed{7.4\times10^{-10}\,\mathrm{F}}$$

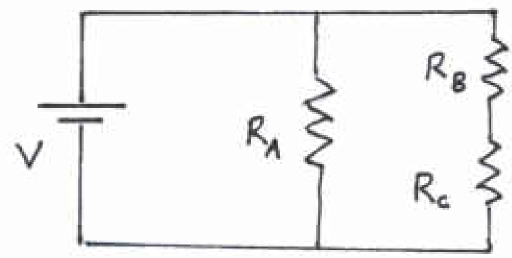
e) Find the magnitude of the force on a $+2.0\,\mu\mathrm{C}$ charge when it is between the plates. (3)

Force, E-field and charge related by $F = qE$, so

$$F = (2.0\times10^{-6}\,\mathrm{C})(1.36\times10^{6}\,\tfrac{\mathrm{N}}{\mathrm{C}}) = \boxed{2.7\,\mathrm{N}}$$

On this one, you *may* wish to answer the parts in a different order from the way they are given here.

6. A simple circuit is formed from a battery and three resistors configured as shown at the right.



$V = 9.0\,V$ $R_A = 3.0\,\Omega$ $R_B = 3.0\,\Omega$ $R_C = 6.0\,\Omega$

a) Find the equivalent resistance of the circuit.(5)

R_B and R_C combine to give and equiv. res. of $3.0\,\Omega + 6.0\,\Omega = 9.0\,\Omega$. This combines in parallel with R_A, giving:

$$\frac{1}{R_{eq}} = \frac{1}{3.0\,\Omega} + \frac{1}{9.0\,\Omega} = 0.444\,\Omega^{-1} \longrightarrow \boxed{R_{eq} = 2.25\,\Omega}$$

b) Find the total current in the circuit.(3)

Use R_{eq} w/ V to get the total current:

$$I_{Tot} = \frac{V}{R_{eq}} = \frac{(9.0\,V)}{(2.25\,\Omega)} = \boxed{4.0\,A}$$

c) What is the voltage drop across R_A? (2)

This is simply equal to the battery voltage since the battery is connected to both ends!

$$\longrightarrow V_A = 9.0\,V$$

d) What is the current which flows through R_A? (3)

Ohm's Law for resistor R_A gives:

$$I_A = \frac{V_A}{R_A} = \frac{(9.0\,V)}{(3.0\,\Omega)} = \boxed{3.0\,A}$$

e) What is the voltage drop across the *combination* of R_B and R_C? (4)

Again, the battery is connected across this combination (which has equiv. resistance $9.0\,\Omega$) so the voltage drop is

$$V_{B\&C} = 9.0\,V$$

f) Find the current that passes through R_B and R_C. (3)

The resistance of the combination is $9.0\,\Omega$ so Ohm's Law and our answer for (e) gives us:

$$I_{B\&C} = \frac{V_{B\&C}}{R_{B\&C}} = \frac{(9.0\,V)}{(9.0\,\Omega)} = \boxed{1.0\,A}$$

The answers to (d) and (f) do add up to give the total current, 4.0 A in part (b)!

7. When a potential of 120 V is applied to the ends of a copper wire of length 50.0 m, a current of 20.0 A flows in the wire. The wire has circular cross-section; the resistivity of copper is $1.72 \times 10^{-8}\,\Omega \cdot \text{m}$

a) What is the resistance of the wire? (3)

Ohm's Law for the entire length of wire gives:

$$R = \frac{V}{I} = \frac{(120\,\text{V})}{(20.0\,\text{A})} = \boxed{6.00\,\Omega}$$

b) What is the cross-sectional area of the wire? (5)

Use $R = \rho L/A$. Solve for A:

$$A = \frac{\rho L}{R} = \frac{(1.72\times10^{-8}\,\Omega\cdot\text{m})(50.0\,\text{m})}{(6.00\,\Omega)} = \boxed{1.43\times10^{-7}\,\text{m}^2}$$

c) What is the radius of the wire's cross-section? (3)

Wire has circular cross-section, so $A = \pi r^2$. Use answer to (b), then

$$r^2 = A/\pi = (1.43\times10^{-7}\,\text{m}^2)/\pi = 4.6\times10^{-8}\,\text{m}^2$$

$$\rightarrow r = \boxed{2.1\times10^{-4}\,\text{m} = 0.21\,\text{mm}}$$

8. Below is shown a permanent (bar) magnet, with its poles labelled.

Sketch in a few representative magnetic field lines, showing their directions. (4)