Name ______________________

Feb. 23, 2006

Phys 2020, NSCC
Exam #1 — Spring 2006

1.	______	(16)
2.	______	(10)
3.	______	(15)
4.	______	(6)
5.	______	(20)
6.	______	(10)
7.	______	(8)
8.	______	(5)
MC	______	(10)
Total	______	(100)

Multiple Choice

Choose the best answer from among the four!

1. According to Coulomb's law, if we change the distance between two point charges by a factor of $\times 4$, the force between them changes by a factor of

a) $\times\frac{1}{16}$
b) $\times\frac{1}{4}$
c) $\times 2$
d) $\times 4$

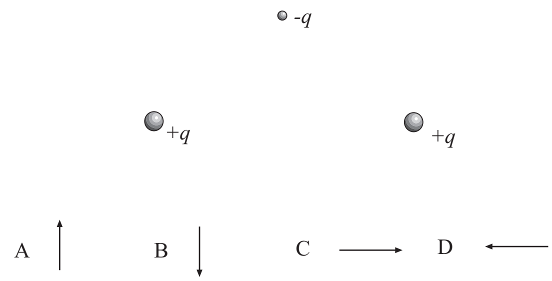
2. A negative charge $-q$ is in the vicinity of two positive charges $+q$, as shown. Which vector gives the direction of the force on the chage $-q$?

a) **A**

b) **B**

c) **C**

d) **D**



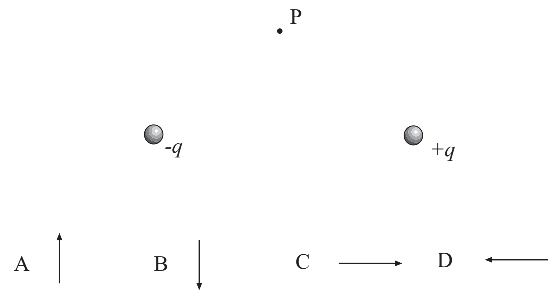
3. Point P is in the vicinity of a negative charge $-q$ and a positive charge $+q$. Which vector gives the direction of the electric field at P?

a) **A**

b) **B**

c) **C**

d) **D**



4. A Volt is equal to

a) $1\,\frac{\mathrm{J}}{\mathrm{C}}$

b) $1\,\frac{\mathrm{N}}{\mathrm{C}}$

c) $1\,\frac{\mathrm{C}}{\mathrm{m}}$

d) $1\,\frac{\mathrm{C}}{\mathrm{s}}$

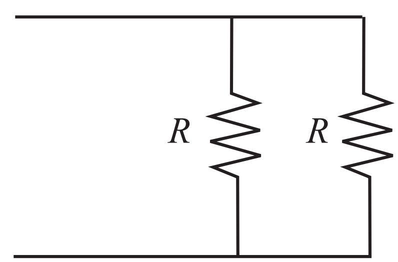
5. When two resistors of value R are connected in parallel the resistance of the combination is

a) Always less than R.

b) Always greater then R.

c) Always equal to R.

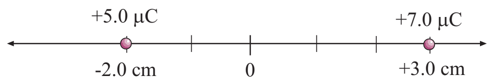
d) Can be greater or less than R, depending on the value of R.



Problems

Show your work and include the correct units with your answers!

1. On the x axis, $+5.0\,\mu$C and $+7.0\,\mu$C charges are located at $x = -2.0$ cm and $x = +3.0$ cm, respectively.



a) Find the magnitude and direction of the electric field at the origin. (10)

The charge at $x = -2.0$ cm gives an E field in the $+x$ direction of magnitude

$$E_1 = k\frac{|q|}{r^2} = (8.99 \times 10^9 \ \tfrac{\mathrm{N \cdot m^2}}{\mathrm{C^2}})\frac{(5.0 \times 10^{-6}\ \mathrm{C})}{(2.0 \times 10^{-2}\ \mathrm{m})^2} = 1.12 \times 10^8 \ \tfrac{\mathrm{N}}{\mathrm{C}}$$

The charge at $x = +3.0$ cm gives an E field in the $-x$ direction of magnitude

$$E_2 = k\frac{|q|}{r^2} = (8.99 \times 10^9 \ \tfrac{\mathrm{N \cdot m^2}}{\mathrm{C^2}})\frac{(7.0 \times 10^{-6}\ \mathrm{C})}{(3.0 \times 10^{-2}\ \mathrm{m})^2} = 6.99 \times 10^7 \ \tfrac{\mathrm{N}}{\mathrm{C}}$$

So the x component of the (total) E field is

$$E_x = 1.12 \times 10^8 \ \tfrac{\mathrm{N}}{\mathrm{C}} - 6.99 \times 10^7 \ \tfrac{\mathrm{N}}{\mathrm{C}} = +4.24 \times 10^7 \ \tfrac{\mathrm{N}}{\mathrm{C}}$$

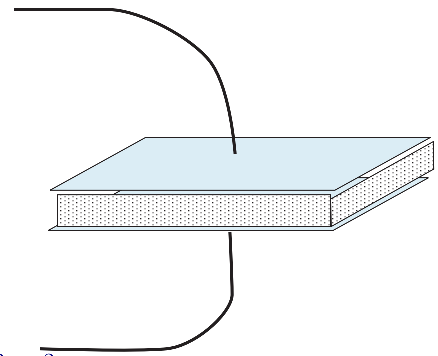
(So this is also the magnitude of the E field, which points in the $+x$ direction.

b) If a $-3.0\,\mu$C charge is placed at the origin, what is the magnitude and direction of the force on that charge? (The answer to part (a) could be useful.) (6)

Use $\mathbf{F} = q\mathbf{E}$, since from (a) we have the E field. Since q here is negative and the E field points in the $+x$ direction, the force is in the $-x$ direction and has magnitude

$$F = |q|E = (3.0 \times 10^{-6})(4.24 \times 10^7 \ \tfrac{\mathrm{N}}{\mathrm{C}}) = 127 \ \mathrm{N}$$

2. A parallel-plate capacitor is made from two plates of area 400 cm^2 separated by a distance of 0.30 mm with the space in between filled with a dielectric with dielectric constant 5.0.



a) What is the value of its capacitance? (7)

Use the formula for the capacitance of parallel plates along with the factor for the dielectric constant, $C = \kappa C_{\mathrm{air}}$. The area of the plates is

$$A = 400 \times 10^{-4}\ \mathrm{m}^2 = 4.0 \times 10^{-2}\ \mathrm{m}^2$$

so this gives

$$\begin{aligned} C &= \kappa \frac{\epsilon_0 A}{d} = (5.0) \frac{(8.85 \times 10^{-12}\ \frac{\mathrm{C}^2}{\mathrm{N}})(4.0 \times 10^{-2}\ \mathrm{m}^2)}{(0.30 \times 10^{-3}\ \mathrm{m})} \\ &= 5.9 \times 10^{-9}\ \mathrm{F} = 5.9\ \mathrm{nF} \end{aligned}$$

b) If a potential difference of 400 V is applied across the plates, how much charge is stored? (3)

For a capacitor, charge and voltage are related by $q = CV$, so

$$q = CV = (5.9 \times 10^{-9}\ \mathrm{F})(400\ \mathrm{V}) = 2.4 \times 10^{-6}\ \mathrm{C} = 2.4\,\mu\mathrm{C}$$

3. A alpha particle (charge $+2e$ and mass 6.64×10^{-27} kg) starts from rest and is accelerated as it moves through a decrease in electric potential of magnitude 1.0 kV.

a) What is the change in electric *potential energy* of the alpha particle? (Express the answer in joules.) (8)

The change in the electric potential energy of the particle is $q\Delta V$, which is

$$\Delta\text{EPE} = 2(1.60 \times 10^{-19}\ \text{C})(-1.0 \times 10^{3}\ \text{V}) = -3.2 \times 10^{-16}\ \text{J}$$

b) What is the final speed of the alpha particle? (7)

The change in kinetic energy of the particle is the opposite of the change in potential energy, since total energy is conserved. Since the particle starts from rest, the answer to (a) tells us that the kinetic energy of the alpha particle must be 3.2×10^{-16} J, so solving for v,

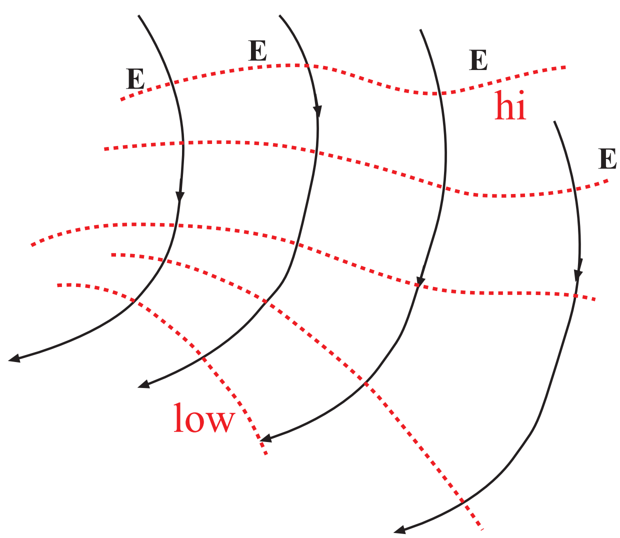
$$\tfrac{1}{2}mv^2 = 3.2 \times 10^{-16}\ \text{J} \qquad \Longrightarrow \qquad v^2 = \frac{2(3.2 \times 10^{-16}\ \text{J})}{(6.64 \times 10^{-27}\ \text{kg})} = 9.64 \times 10^{10}\ \tfrac{\text{m}^2}{\text{s}^2}$$

and then

$$v = 3.1 \times 10^{5}\ \tfrac{\text{m}}{\text{s}}$$

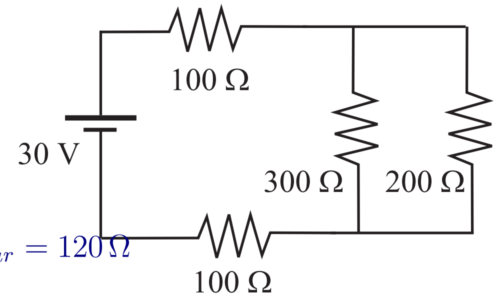
4. For the electric field shown at the right, sketch in a few equipotential lines. Indicate which of your lines has the lowest potential and which has the highest. (6)

Equipotentials are shown; there are *perpendicular* to the field lines. Now, field lines go from regions of high potential to regions of low potential so the higher and lower equipotentials are labelled as shown.



5. For the electric circuit shown at the right, find:

a) The total current. (9)



The 200 and $300\,\Omega$ resistors are in parallel; their equivalent resistance is

$$\frac{1}{R_{par}} = \frac{1}{200\,\Omega} + \frac{1}{300\,\Omega} = 8.33\times10^{-3}\,\Omega^{-1} \qquad \Longrightarrow \qquad R_{par} = 120\,\Omega$$

This combination is in *series* with the two $100\,\Omega$ resistors giving an equivalent resistance for the circuit of

$$R_{eq} = 100\,\Omega + 120\,\Omega + 100\,\Omega = 320\,\Omega$$

Then the total current in the circuit is

$$I = \frac{V}{R_{eq}} = \frac{30\ \mathrm{V}}{320\,\Omega} = 9.38 \times 10^{-2}\ \mathrm{A}$$

b) The current in the $200\,\Omega$ resistor. (8)

The current found in (a) is the current in each of the $100\,\Omega$ resistors. Adding up the potential differences, the potential difference across the parallel combination is

$$V_{par} = -(9.38 \times 10^{-2}\ \mathrm{A})(100\,\Omega) + 30\ \mathrm{V} - (9.38 \times 10^{-2}\ \mathrm{A})(100\,\Omega) = 11.2\ \mathrm{V}$$

This is the voltage across the $200\,\Omega$ resistor, so the current in that resistor is

$$I = \frac{V}{R} = \frac{11.2\ \mathrm{V}}{200\,\Omega} = 5.62 \times 10^{-2}\ \mathrm{A}$$

c) The power dissipated in the $200\,\Omega$ resistor. (3)

We have the current in this resistor from (b), so the power dissipated is

$$P = I^2R = (5.62 \times 10^{-2}\ \mathrm{A})^2(200\,\Omega) = 0.633\ \mathrm{W}$$

6. We want to take a length of copper wire so that it has a resistance of $0.10\,\Omega$. The wire has circular cross-section with a radius of 0.30 mm.

What length of wire should we take? The resistivity of copper is $1.7 \times 10^{-8}\,\Omega\cdot\mathrm{m}$ (10)

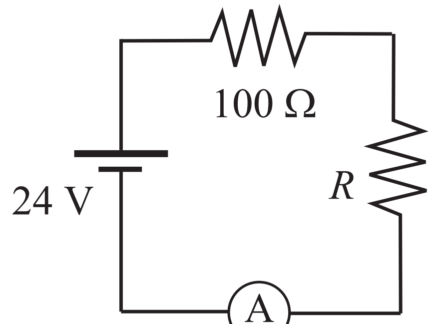
The xsection area of the wire is

$$A = \pi r^2 = \pi(0.30 \times 10^{-3}\ \mathrm{m})^2 = 2.8 \times 10^{-7}\ \mathrm{m}^2$$

so using $R = \rho\frac{L}{A}$ and solving for L,

$$L = \frac{RA}{\rho} = \frac{(0.10\,\Omega)(2.8 \times 10^{-7}\ \mathrm{m}^2)}{(1.7 \times 10^{-8}\,\Omega\cdot\mathrm{m})} = 1.66\ \mathrm{m}$$

7. A $100\,\Omega$ resistor and an unknown resistor R and an ammeter are connected to a 24.0 V battery as shown at the right. When this is down, the ammeter reads 0.140 A.
What is the value of the resistor R? (8)



Using $V = IR$, The total resistance of the circuit must be

$$R_{tot} = \frac{V}{I} = \frac{24.0\ \text{V}}{0.140\ \text{A}} = 171\,\Omega$$

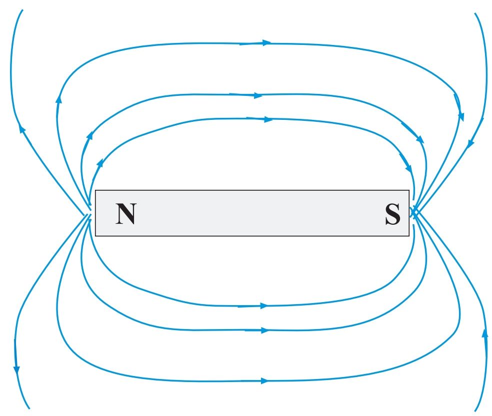
but this total resistance arises from a $100\,\Omega$ resistor in series with R. Then we must have

$$171\,\Omega = 100\,\Omega + R$$

which gives

$$R = 71\,\Omega$$

8. For the bar magnet shown below, sketch in some magnetic field lines to show the direction of the field around the magnet (5)



You must show all your work and include the right units with your answers!

$$F = k\frac{|q_1 q_2|}{r^2} \qquad k = \frac{1}{4\pi\epsilon_0} \qquad \mathbf{F} = q\mathbf{E} \qquad E = k\frac{q}{r^2} \qquad E_{\text{plates}} = \frac{\sigma}{\epsilon_0}$$

$$\Delta\text{EPE} = \Delta U_{\text{elec}} = q\Delta V \qquad V = -\frac{\Delta E_s}{\Delta s} \qquad V = k\frac{q}{r} \qquad 1\ \text{eV} = 1.602 \times 10^{-19}\ \text{J}$$

$$q = CV \qquad C = \epsilon_0 \frac{A}{d} \qquad \text{Energy} = \tfrac{1}{2}CV^2 \qquad C_{\text{diel}} = \kappa C_{\text{vac}}$$

$$V = IR \qquad R = \rho\frac{L}{A} \qquad P = IV = I^2 R$$

$$R_{\text{ser}} = R_1 + R_2 \ldots \qquad \frac{1}{R_{\text{par}}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots \qquad \sum I_{in} = \sum I_{out} \qquad \sum_{\text{loop}} V = 0$$

$$k = 8.99 \times 10^9\ \tfrac{\text{N}\cdot\text{m}^2}{\text{C}^2} \qquad \epsilon_0 = 8.85 \times 10^{-12}\ \tfrac{\text{C}^2}{\text{N}} \qquad e = 1.602 \times 10^{-19}\ \text{C} \qquad A = \pi r^2$$