Name______________________________

Feb. 21, 2008

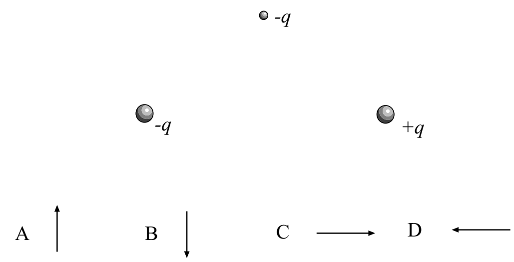
Phys 2020, NSCC
Exam #1 — Spring 2008

1.	________________	(8)
2.	________________	(8)
3.	________________	(14)
4.	________________	(10)
5.	________________	(8)
6.	________________	(8)
7.	________________	(20)
8.	________________	(8)
9.	________________	(6)
MC	________________	(10)
Total	________________	(100)

Multiple Choice

Choose the best answer from among the four! (2) each.

1. A negative charge $-q$ is in the vicinity of two charges $\pm q$, as shown. Which vector gives the direction of the force on the charge $-q$?



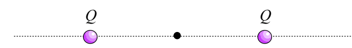
a) A

b) B

c) C

$\boxed{\textbf{d)}}$ D

2. At the point which is precisely between two equal point charges



$\boxed{\textbf{a)}}$ The electric field is zero, but the electric potential is not zero.

b) The electric field is not zero, but the electric potential is zero.

c) Neither the field nor the potential is zero.

d) Both the field and potential are zero.

3. A Farad is equal to

$\boxed{\textbf{a)}}$ $\frac{\mathrm{C}}{\mathrm{V}}$

b) $\frac{\mathrm{V}}{\mathrm{C}}$

c) $\frac{\mathrm{N}}{\mathrm{V}}$

d) $\frac{\mathrm{V}}{\mathrm{N}}$

4. If we put a resistor R and a resistor $2R$ in parallel, the equivalent resistance of the combination is

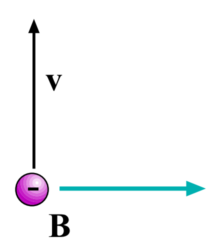
a) $\frac{1}{3}R$

$\boxed{\textbf{b)}}$ $\frac{2}{3}R$

c) $\frac{3}{2}R$

d) $3R$

5. A *negative* charge moves in the plane of the page, in the "up" direction in a uniform magnetic field which points to the right. The force on the charge is



a) Into the page.

$\boxed{\textbf{b)}}$ Out of the page.

c) Up.

d) Down.

Problems

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

1. Two 15.0 nC point charges expert a mutual force of repulsion of 1.5×10^{-3} N. What is the distance between the charges? (8)

We are given F and the values of the two charges (same charge q) so Coulomb's law gives

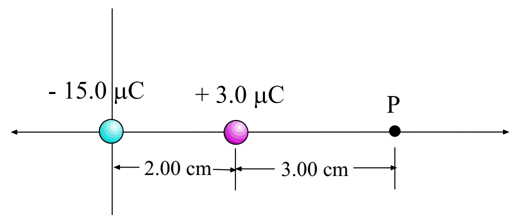
$$F = k\frac{q^2}{r^2} \qquad \Longrightarrow \qquad r^2 = k\frac{q^2}{F} = (8.99 \times 10^9 \, \tfrac{\mathrm{N \cdot m^2}}{\mathrm{C^2}})\frac{(15.0 \times 10^{-9} \ \mathrm{C})^2}{(1.5 \times 10^{-3} \ \mathrm{N})} = 1.35 \times 10^{-3} \ \mathrm{m}^2$$

Then:

$$r = 3.67 \times 10^{-2} \ \mathrm{m} = 3.67 \ \mathrm{cm}$$

2. Two charges are on the x axis: A $-15.0\,\mu$C charge is at the origin and a $+3.0\,\mu$C charge is at $x = 2.00$ cm.

Find the electric field at the point P, which is 3.00 cm farther out along the x axis. (Give its magnitude and direction.) (8)



The field due to the charge at the origin points *toward* that charge (i.e. the $-x$ direction) and since its distance from P is 5.0 cm, it has magnitude

$$E = k\frac{|q|}{r^2} = (8.99 \times 10^9 \, \tfrac{\mathrm{N \cdot m^2}}{\mathrm{C^2}})\frac{(15.0 \times 10^{-6} \ \mathrm{C})}{(5.0 \times 10^{-2} \ \mathrm{m})^2} = 5.39 \times 10^7 \, \tfrac{\mathrm{N}}{\mathrm{C}}$$

The field due to the second charge points away from that charge, i.e. in the $+x$ direction and since its distance from P is 3.0 cm, it has magnitude

$$E = k\frac{|q|}{r^2} = (8.99 \times 10^9 \, \tfrac{\mathrm{N \cdot m^2}}{\mathrm{C^2}})\frac{(3.0 \times 10^{-6} \ \mathrm{C})}{(3.0 \times 10^{-2} \ \mathrm{m})^2} = 3.00 \times 10^7 \, \tfrac{\mathrm{N}}{\mathrm{C}}$$

Then the total E field at P is

$$E_x = -5.39 \times 10^7 \, \tfrac{\mathrm{N}}{\mathrm{C}} + 3.00 \times 10^7 \, \tfrac{\mathrm{N}}{\mathrm{C}} = -2.39 \times 10^7 \, \tfrac{\mathrm{N}}{\mathrm{C}}$$

that is, it has magnitude $2.39 \times 10^7 \, \frac{\mathrm{N}}{\mathrm{C}}$ and points in the $-x$ direction.

3. Two conducting parallel plates, each of area 20.0 cm^2 are separated by 5.00 mm. (There is air between the plates.) A potential difference of 100.0 V is applied across the plates. Find:

a) The charge that collects on each plate. (8)

The capacitance of the plates is

$$C = \epsilon_0 \frac{A}{d}$$

Since the area is

$$A = (20.0 \times 10^{-4}\ \text{m})^2 = 2.00 \times 10^{-3}\ \text{m}^2$$

we get

$$C = (8.85 \times 10^{-12}) \frac{(2.00 \times 10^{-3}\ \text{m}^2)}{(5.00 \times 10^{-3}\ \text{m})} = 3.54 \times 10^{-12}\ \text{F} = 3.54\ \text{pF}$$

Then we can use $Q = CV$ to get the charge:

$$Q = (3.54 \times 10^{-12}\ \text{F})(100\ \text{V}) = 3.54 \times 10^{-10}\ \text{C}$$

b) The magnitude of the electric field between the plates. (2)

Use $E = \frac{\Delta V}{\Delta s}$ to get the magnitude of E:

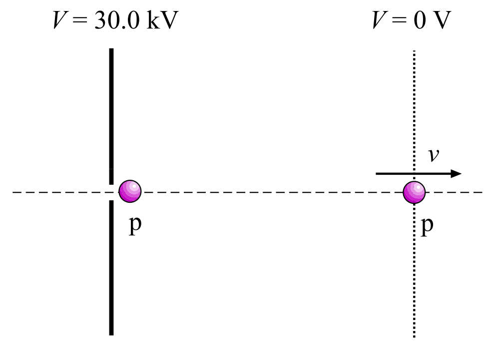
$$E = \frac{(100\ \text{V})}{(5.00 \times 10^{-3}\ \text{m})} = 2.00 \times 10^4\ \frac{\text{N}}{\text{C}}$$

c) The magnitude of the force on a particle of charge $+e$ if it is in the space between the plates. (4)

The magnitude of the force (on charge $q = e$) is

$$F = qE = (1.60 \times 10^{-19}\ \text{C})(2.00 \times 10^4\ \tfrac{\text{N}}{\text{C}}) = 3.2 \times 10^{-15}\ \text{N}$$

4. A proton is accelerated by having it move through a potential difference of 30.0 kV, starting from rest. In doing so, it loses potential energy and gains kinetic energy.



a) Find the loss in electric potential energy the proton undergoes. (4)

The change in potential is $-30.0\ \mathrm{kV}$, so the change in potential energy is

$$\Delta\mathrm{EPE} = q\Delta V = (1.60 \times 10^{-19}\ \mathrm{C})(-30.0 \times 10^{3}\ \mathrm{V}) = -4.8 \times 10^{15}\ \mathrm{J}$$

that is, it loses $\boxed{4.8 \times 10^{15}\ \mathrm{J}}$ of potential energy.

b) Find the final speed of the proton. (The mass of the proton is 1.67×10^{-27} kg.) (6)

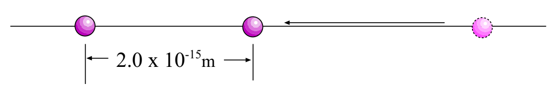
From (a), the proton must gain 4.8×10^{15} J of kinetic energy. Then:

$$\mathrm{KE} = \tfrac{1}{2}mv^2 \qquad \Longrightarrow \qquad v^2 = \frac{2\mathrm{KE}}{m} = \frac{2(4.8 \times 10^{-15}\ \mathrm{J})}{(1.67 \times 10^{-27}\ \mathrm{kg})} = 5.75 \times 10^{12}\ \tfrac{\mathrm{m}^2}{\mathrm{s}^2}$$

Then:

$$v = 2.40 \times 10^{6}\ \tfrac{\mathrm{m}}{\mathrm{s}}$$

5. Find the work required to bring a proton from far away up to 2.0×10^{-15} m away from another proton. (Hint: Find the change in electrical potential energy of the second proton.) (8)



With the first proton fixed at the origin, we find the electrical potential of the second proton when it is at infinity and when it is near the other proton. In both cases, use $V = k\frac{q}{r} = +k\frac{e}{r}$. At infinity, the potential is zero. At the given distance it is

$$V_2 = k\frac{e}{r} = (8.99 \times 10^{9}\ \tfrac{\mathrm{N\cdot m^2}}{\mathrm{C^2}})\frac{(1.60 \times 10^{-19}\ \mathrm{C})}{(2.0 \times 10^{-15}\ \mathrm{m})} = 7.19 \times 10^{5}\ \mathrm{V}$$

The work required is the change in potential energy, so

$$W = q\Delta V = (1.60 \times 10^{-19}\ \mathrm{C})(7.19 \times 10^{5}\ \mathrm{V} - 0) = 1.15 \times 10^{-13}\ \mathrm{J}$$

6. We need to make a resistor of resistance $5.00\,\Omega$ from a length of copper wire which has a circular cross-section of radius 0.200 mm.

What length should we take? (The resistivity of copper is $1.72 \times 10^{-8}\,\Omega\cdot\mathrm{m}$.) (8)

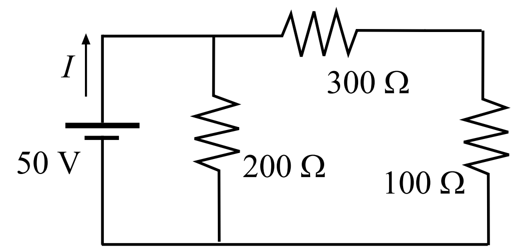
The cross-sectional area of the wire is

$$A = \pi r^2 = \pi(0.200 \times 10^{-3}\ \mathrm{m})^2 = 1.26 \times 10^{-7}\ \mathrm{m}^2$$

We are given R and the resistivity of copper, so we use

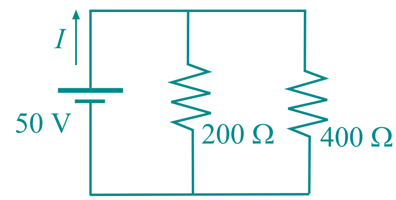
$$R = \rho\frac{L}{A} \qquad \Longrightarrow \qquad L = \frac{RA}{\rho} = \frac{(5.00\,\Omega)(1.26 \times 10^{-7}\ \mathrm{m}^2)}{(1.72 \times 10^{-8}\,\Omega\cdot\mathrm{m})} = 36.6\ \mathrm{m}$$

7. In the circuit shown here, find:



a) The total current, I (6)

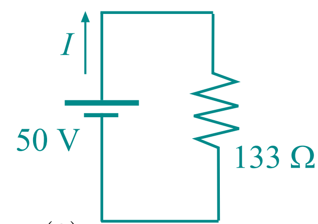
The first step in finding the total current is to combine the two series resistors into one resistor, as is done at the right. Then we have a $400\,\Omega$ and $200\,\Omega$ resistor in parallel which we combine using the parallel rule:



$$\frac{1}{R_{\rm eq}} = \frac{1}{400\,\Omega} + \frac{1}{200\,\Omega} \qquad \Longrightarrow \qquad R_{\rm eq} = 133\,\Omega$$

which gives the reduced circuit shown here.

This gives us the total current I from Ohm's law:



$$I = \frac{V}{R_{\rm eq}} = \frac{(50.0\ \mathrm{V})}{(133\,\Omega)} = 0.375\ \mathrm{A}$$

b) The current in the $200\,\Omega$ resistor and the current in the $300\,\Omega$ resistor (8)

The potential drop across the $200\,\Omega$ resistor must be $50.0\ \mathrm{V}$ since it is directly connected across the ends of the battery. Ohm's law gives us the current in this resistor:

$$I_{200} = \frac{V}{R} = \frac{(50.0\ \mathrm{V})}{(200\,\Omega)} = 0.250\ \mathrm{A}$$

By the junction rule, the current which goes through the other two resistors in series is

$$I_{300} = I_{100} = 0.375\ \mathrm{A} - 0.250\ \mathrm{A} = 0.125\ \mathrm{A}$$

c) The potential difference across the $100\,\Omega$ resistor. (4)

The current in the $100\,\Omega$ resistor is the same as that in the $300\,\Omega$ resistor and so the potential drop across the $100\,\Omega$ resistor is

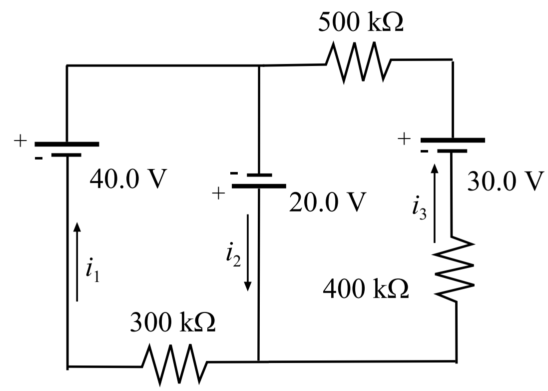
$$V_{100} = I_{100}R = (0.125\ \mathrm{A})(100\,\Omega) = 12.5\ \mathrm{V}$$

d) The power dissipated in the $100\,\Omega$ resistor. (2)

We have the current through this resistor so the power dissipated is

$$P_{100} = I^2R = (0.125\ \mathrm{A})^2(100\,\Omega) = 1.56\ \mathrm{W}$$

8. Consider the messy circuit shown at the left; it has three batteries (note the direction of their polarities!) and several resistors. We would like to solve for the currents in all three branches. For your convenience I have assigned and labelled these currents in the figure.



Write down (clearly, please) three equations that would allow us to solve for i_1, i_2 and i_3. You *don't* need to solve these equations for these currents. (8)

Using the currents as defined in the diagram, the junction rule (at either the top or bottom junction point) gives:

$$i_1 + i_3 = i_2$$

Choosing a clockwise path round the left loop, the loop rule gives us

$$+40.0\ \text{V} + 20.0\ \text{V} - i_1(300\, k\Omega) = 0$$

Choosing a counterclockwise path around the right loop, we get

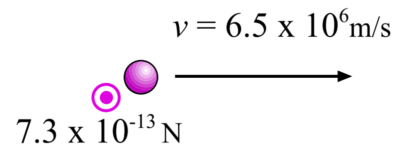
$$+20.0\ \text{V} - i_3(400\, k\Omega) + 30.0\ \text{V} - i_3(500\, k\Omega) = 0$$

Actually these equations are quite easy to solve the for three currents. We get:

$$i_1 = 0.200\ \text{mA} \qquad i_3 = 0.055\ \text{mA} \qquad i_2 = 0.255\ \text{mA}$$

9. A proton is moving to the right in a uniform magnetic field with speed $6.5 \times 10^6 \, \frac{\mathrm{m}}{\mathrm{s}}$. The force on the proton has magnitude 7.3×10^{-13} N and is directed out of the page.

Find the magnitude and direction of the magnetic field. (6)



Since the proton has a positive charge, we find from the right-hand rule for magnetic forces that the field must be pointing $\boxed{\text{up}}$ (in the plane of the page) in order for there to be a force out of the page.

To get the magnitude of the field (since $\mathbf{v}$ is perpendicular to $\mathbf{B}$), use

$$F = qvB \qquad \Longrightarrow \qquad B = \frac{F}{qv} = \frac{(7.3 \times 10^{-13}\ \mathrm{N})}{(1.6 \times 10^{-19}\ \mathrm{C})(6.5 \times 10^6 \, \frac{\mathrm{m}}{\mathrm{s}})} = 0.702\ \mathrm{T}$$

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

$$\mathbf{F} = m\mathbf{a} \qquad F_c = \frac{mv^2}{r} \qquad \mathrm{KE} = \tfrac{1}{2}mv^2$$

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

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

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

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

$$\sum I_{in} = \sum I_{out} \qquad \sum_{\mathrm{loop}} V = 0 \qquad F = qvB\sin\theta$$

$$r = \frac{mv}{|q|B} \qquad m = \left(\frac{qr^2}{2V}\right)B^2 \qquad F = ILB\sin\theta \qquad \tau = NIAB\sin\phi$$

$$k = 8.99 \times 10^9\ \frac{\mathrm{N \cdot m^2}}{\mathrm{C^2}} \qquad \epsilon_0 = 8.854 \times 10^{-12}\ \frac{\mathrm{C^2}}{\mathrm{N \cdot m^2}} \qquad e = 1.602 \times 10^{-19}\ \mathrm{C} \qquad A = \pi r^2$$