Units?
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Name____________________

Feb. 19, 2004

Phys 2020 — Spring 2004
Exam #1

1. ____________ (7)

2. ____________ (10)

3. ____________ (18)

4. ____________ (15)

5. ____________ (8)

6. ____________ (22)

MC ____________ (20)

Total ____________ (100)

$$k = \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9\,\frac{\mathrm{N{\cdot}m^2}}{\mathrm{C^2}} \qquad \epsilon_0 = 8.85 \times 10^{-12}\,\frac{\mathrm{C^2}}{\mathrm{N{\cdot}m^2}} \qquad e = 1.602 \times 10^{-19}\,\mathrm{C}$$

$$A = \pi r^2 \qquad \mathbf{F} = m\mathbf{a} \qquad \mathrm{KE} = \tfrac{1}{2}mv^2 \qquad g = 9.80\,\tfrac{\mathrm{m}}{\mathrm{s}^2} \qquad m_{\mathrm{elec}} = 9.1094 \times 10^{-31}\,\mathrm{kg}$$

$$F = k\frac{|q_1 q_2|}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{|q_1 q_2|}{r^2} \qquad \mathbf{F} = q\mathbf{E} \qquad E_{\mathrm{pt\ ch}} = k\frac{|q|}{r^2} \qquad E_{\mathrm{par-pl}} = \frac{|q|}{\epsilon_0 A} = \frac{|\sigma|}{\epsilon_0}$$

$$\Delta\mathrm{EPE} = q\Delta V \qquad V_{\mathrm{pt\ ch}} = k\frac{q}{r} \qquad \mathrm{EPE} = k\frac{q_1 q_2}{r} \qquad |E_x| = \left|\frac{\Delta V}{\Delta x}\right|$$

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

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

$$P = VI = I^2 R = \frac{V^2}{R} \qquad \mathrm{Energy} = Pt \qquad 1\,\mathrm{eV} = 1.602 \times 10^{-19}\,\mathrm{J}$$

Multiple Choice

Choose the best answer from among the four!

1. A object with a (net) charge of -1.602×10^{-8} C has an excess of how many electrons?

a) 10^{27}

b) 10^{11}

c) 10^{8}

d) 10

2. If the repulsive force between two point charges is F when they are separated by a distance R, when the distance is reduced to $R/3$ the repulsive force is

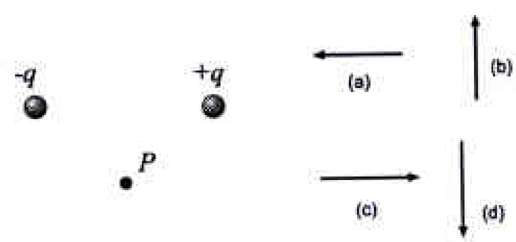
a) $F/9$

b) $F/3$

c) $3F$

d) $9F$.

3. When you are at point P, the direction of the electric field due to the point charges $-q$ and $+q$ is given by:



a) (a)

b) (b)

c) (c)

d) (d)

4. The electric field between two large comducting parallel plates with opposite charges

a) Is zero midway between the plates.

b) Has maximum magnitude near the positive plate.

c) Has maximum magnitude near the negative plate.

d) Has the same value everywhere except near the edges.

5. The electric potential at a certain point in space is 15.0 V. What is the electric potential energy of a $-3.0\,\mu$C charge placed at this point?

a) $-45\,\mu$J

b) $-5.0\,\mu$J

c) $+5.0\,\mu$J

d) $+45\,\mu$J

6. Electric field lines

a) Must begin on a negative charge and end on a positive charge.

b) Must begin on a positive charge and end on a negative charge.

c) Can begin *or* end on a positive charge.

d) Cannot begin or end on a postivie charge.

7. A completely ionized lithium atom (net charge = $+3e$) is accelerated through a potential difference of 6.0 V. What is the increase in kinetic energy of the atom?

a) 0.50 eV

b) 2.0 eV

c) 3.0 eV

d) 18.0 eV

8. When two resistors (each of resistance R) are connected in parallel, the equivalent resistance is

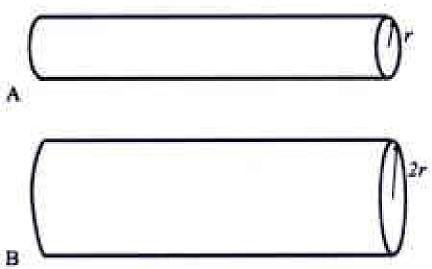
a) $4R$

b) $2R$

c) R

d) $R/2$

9. Wires A and B have the same length but wire B has twice the radius of wire A. If the resistance of wire A is R, the resistance of B is



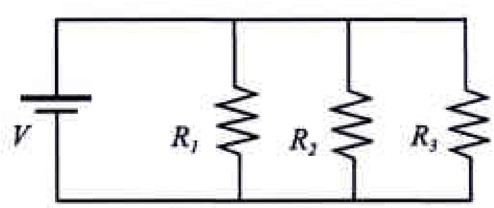
a) $R/4$

b) $R/2$

c) $2R$

d) $4R$

10. In the circuit shown at the right, if R_3 is removed, the current through R_1



a) Will always increase.

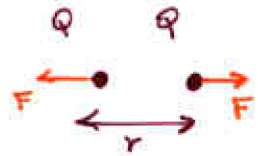
b) Will always decrease.

c) Will stay the same.

d) Could increase or decrease depending on the values of the resistances.

Problems

1. Two 6.0 μC point charges exert a repulsive force of 1.40 N on each other. What is the distance between the two charges? (7)



Since $F = k\frac{|q_1 q_2|}{r^2} = k\frac{Q^2}{r^2}$, with $Q = 6.0\mu C$,

use $r^2 = kQ^2/F$, then:

$$r^2 = k\frac{Q^2}{F} = (8.99\times10^9)\frac{(6.0\times10^{-6})^2}{(1.40\text{ N})}\text{ m}^2 = 0.231\text{ m}^2$$

So:

$$\boxed{r = 0.481\text{ m}}$$

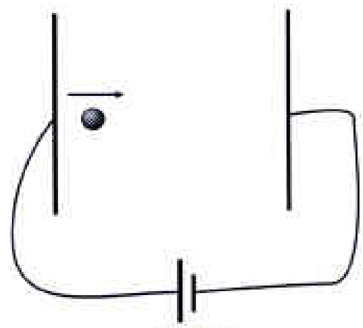
2. A proton (mass 1.67×10^{-27} kg) starts from rest and is accelerated through a potential difference of 2.00×10^4 V

a) What is the change (loss) in potential energy of the proton? (4)

Charge of proton is $+e$, so using $\Delta EPE = q\Delta V$,

$$|\Delta EPE| = |q\Delta V| = (1.602\times10^{-19}\text{C})(2.00\times10^4\text{V})$$

$$= \boxed{3.20\times10^{-15}\text{ J}}$$



20 kV

b) Use energy conservation to find the final speed of the proton. (6)

The proton starts from rest, so the final KE is equal to the loss in potential energy. Then:

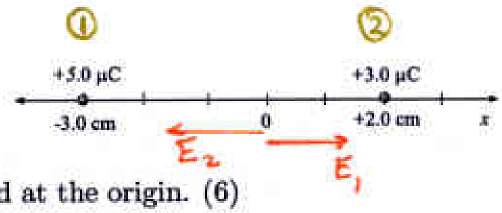
$$\frac{1}{2}mv^2 = 3.20\times10^{-15}\text{ J}$$

$$v^2 = \frac{2(3.20\times10^{-15}\text{ J})}{m} = \frac{2(3.20\times10^{-15}\text{ J})}{(1.67\times10^{-27}\text{ kg})} = 3.84\times10^{12}\ \frac{\text{m}^2}{\text{s}^2}$$

So:

$$v = \boxed{1.96\times10^6\ \frac{\text{m}}{\text{s}}}$$

3. Two point charges lie on the x axis: A $5.00\,\mu$C charge lies at $x = -3.00$ cm and a $3.00\,\mu$C charge lies at $x = 2.00$ cm.



a) Find the magnitude and direction of the electric field at the origin. (6)

Charge ① gives $\vec{E}$ field in $+x$ direction of magnitude

$$E_1 = k\frac{q_1}{r_1^2} = (8.99\times10^9)\frac{(5.0\times10^{-6}\,C)}{(3.0\times10^{-2}\,m)^2} = 4.99\times10^7\ \tfrac{N}{C}$$

Charge ② gives $\vec{E}$ field in $-x$ direction of magnitude

$$E_2 = k\frac{q_2}{r_2^2} = (8.99\times10^9)\frac{(3.0\times10^{-6}\,C)}{(2.0\times10^{-2}\,C)^2} = 6.74\times10^7\ \tfrac{N}{C}$$

The net $\vec{E}$ field is

$$E_x = +4.99\times10^7 - 6.74\times10^7 = -1.75\times10^7\ \tfrac{N}{C}$$

$\rightarrow$ Magnitude is $\boxed{1.75\times10^7\ \tfrac{N}{C}}$

Points in $\boxed{-x}$ direction.

b) Find the value of the electric potential at the origin. (5)

Add up $V_{\text{pt ch}} = k\frac{q}{r}$ for all the point charges:

$$V = k\frac{q_1}{r_1} + k\frac{q_2}{r_2} = (8.99\times10^9)\frac{(5.0\times10^{-6})}{(3.0\times10^{-2})} + (8.99\times10^9)\frac{(3.0\times10^{-6})}{(2.0\times10^{-2})}$$

$$= 2.84\times10^6\ \text{V}$$

c) Now a $-1.00\,\mu$C charge is placed at the origin. Find the magnitude and direction of the force on this charge. (4)

Since $\vec{F} = q\vec{E}$ the x-component of the force is

$$F_x = qE_x = (-1.00\times10^{-6}\,C)(-1.75\times10^7\ \tfrac{N}{C}) = +17.5\ N$$

The force has magnitude $\boxed{17.5\ N}$ and points in the $\boxed{+x}$ direction.

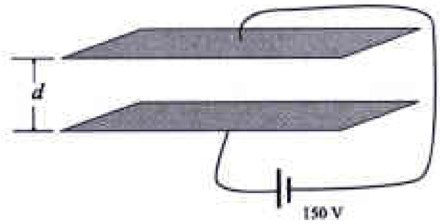
d) How much work is required to move the $-1.00\,\mu$C charge out to infinity (where the potential is zero)? (3)

The potential energy of this charge is $EPE = qV$, so

$$EPE = (-1.00\times10^{-6}\,C)(2.84\times10^6\,V) = -2.84\ J$$

To move it out to infinity (where EPE is zero) requires $\boxed{2.84\ J}$ of work.

4. A parallel plate capacitor is made from two flat conductors with area $300.0\,\mathrm{cm}^2$. When a potential difference of 150.0 V is applied to the plates a charge of $0.300\,\mu\mathrm{C}$ is stored.



a) What is the value of the capacitance? (3)

From $q = CV$ we get:

$$C = \frac{q}{V} = \frac{(0.300\times10^{-6}\,C)}{(150\,V)} = \boxed{2.00\times10^{-9}\,F} = 2.00\,nF$$

b) What is the separation d between the plates? (5)

Using $C = \epsilon_0 \frac{A}{d}$, with $A = 300\,cm^2 = 300\times10^{-4}\,m^2$, get:

$$d = \epsilon_0 \frac{A}{C} = (8.85\times10^{-12})\frac{(300\times10^{-4})}{(2.00\times10^{-9})} = \boxed{1.33\times10^{-4}\,m}$$

c) What is the magnitude of the electric field between the plates? (3)

Use $|E_x| = \left|\frac{\Delta V}{\Delta x}\right| = \frac{V}{d}$, then:

$$|E_x| = \frac{(150\,V)}{(1.33\times10^{-4}\,m)} = \boxed{1.13\times10^{6}\,\frac{V}{m}}$$

d) If the volume between the plates is now filled with a material with dielectric constant 2.5, and the voltage remains at 150.0 V, what charge is now stored on the capacitor? (4)

With $K = 2.5$ the capacitance is now 2.5 times the "air" value:

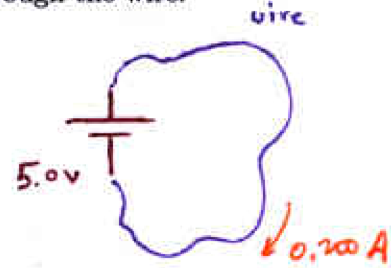
$$C = \kappa C_{air} = (2.5)(2.00\times10^{-9}\,F) = 5.00\times10^{-9}\,F$$

Then with $V = 150\,V$, the charge stored is

$$q = CV = (5.00\times10^{-9}\,F)(150\,V) = \boxed{7.50\times10^{-7}\,C}$$

5. A 10.0 m length of wire has a circular cross-section with a radius of 0.100 mm. When a potential difference of 5.00 V is applied to its ends a current of 0.200 A flows through the wire.

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



From Ohm's law, $V = IR$, get:

$$R = \frac{V}{I} = \frac{(5.00\,\text{V})}{(0.200\,\text{A})} = \boxed{25\,\Omega}$$

b) What is the resistivity of the material? (5)

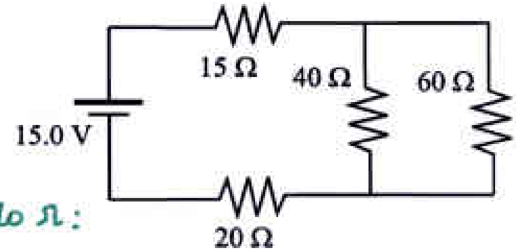
Using $R = \rho\frac{L}{A}$, with $R = 25\,\Omega$ and area A:

$$A = \pi r^2 = \pi(0.100\times10^{-3}\,\text{m})^2 = 3.14\times10^{-8}\,\text{m}^2$$

solve for ρ:

$$\rho = \frac{R\cdot A}{L} = \frac{(25\,\Omega)(3.14\times10^{-8}\,\text{m}^2)}{(10.0\,\text{m})} = \boxed{7.85\times10^{-8}\,\Omega\cdot\text{m}}$$

6. Consider the circuit shown at the right. Find:



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

40Ω and 60Ω give equiv resistance:

$R_{eq} = \left(\frac{1}{40}+\frac{1}{60}\right)^{-1} = 24\,\Omega$

which is then in series w/ 15 Ω and 20 Ω:

$R_{eq} = 15\,\Omega + 24\,\Omega + 20\,\Omega = \boxed{59\,\Omega}$

b) The current in the 20 Ω resistor. (3)

Total current in circuit is

$I = 15\,V/R_{eq} = 15\,V/(59\,\Omega) = 0.254\ A$

and this is the current in the 20 Ω resistor. So $I_{20} = \boxed{0.254\ A}$

c) The potential difference across the 20 Ω resistor. (3)

From Ohm's law, pot'l diff across 20 Ω is

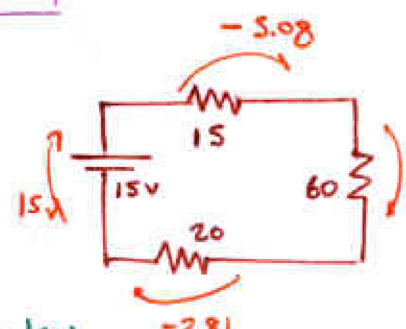
$V_{20} = IR = (0.254\ A)(20\,\Omega) = \boxed{5.08\ V}$

d) The potential difference across the 15 Ω resistor. (2)

The current in the 15 Ω resistor is also 0.254 A so

$V_{15} = IR = (0.254\ A)(15\,\Omega) = \boxed{3.81\ V}$

e) The potential difference across the 60 Ω resistor. (3)



Considering the voltages around the big loop, the pot'l diff. across the 60 Ω must be

$15\,V - 3.81\,V - 5.08\,V = \boxed{6.11\ V}$

f) The current in the 60 Ω resistor. (3)

Pot'l diff across 60 Ω is 6.11 V, so from Ohm's law,

$I_{60} = V/R = (6.11\,V)/(60\,\Omega) = \boxed{0.102\ A}$

g) The power dissipated in the 60 Ω resistor. (3)

$P = I_{60}^2 R = (0.102\ A)^2(60\,\Omega) = \boxed{0.621\ W}$