Units? Units?

Name ______________________

Sept. 25, 2003

Phys 2020 — Fall 2003
Exam #1

1.	______	(11)
2.	______	(4)
3.	______	(16)
4.	______	(11)
5.	______	(6)
6.	______	(7)
7.	______	(7)
8.	______	(18)
MC	______	(20)
Total	______	(100)

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

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

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

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

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

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

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

Multiple Choice

Choose the best answer from among the four!

1. 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 $4R$?

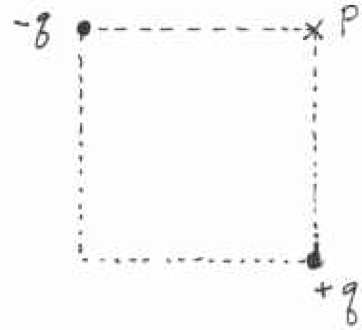
a) $F/16$

b) $F/4$

c) $4F$

d) $16F$

2. Two charges $-q$ and $+q$ sit at opposite corners of a square, as shown. What is the direction of the electric field at the corner labelled P?



a) 

b) 

c) 

d) 

3. If a solid conductor carries any excess charge, the charge

a) Is evenly distributed throughout the volume of the conductor.

b) Resides entirely on the surface of the conductor.

c) Is concentrated at the center of mass of the conductor.

d) Will be concentrated at several points inside the conductor.

4. An aluminum nail has an excess charge of $+3.2\,\mu$C. How many electrons must be added to the nail to make it electrically neutral?

a) 2.0×10^{13}

b) 2.0×10^{19}

c) 3.2×10^{6}

d) 3.2×10^{-6}

5. A Farad is equal to

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

b) $1\,\mathrm{N}\cdot\mathrm{V}$

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

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

6. Which one of the following changes will necessarily increase the capacitance of a capacitor?

a) Decreasing the charge on the plates.

b) Increasing the charge on the plates.

c) Placing a dielectric between the plates.

d) Increasing the potential difference between the plates.

7. If we double the voltage across a capacitor, the energy stored in the capacitor changes by a factor of

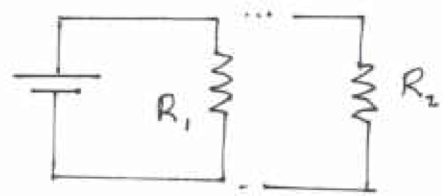
a) $\times \frac{1}{4}$

b) $\times \frac{1}{2}$

c) $\times 2$

d) $\times 4$

8. A circuit contains a single resistor R_1. If another resistor R_2 is combined in parallel with the first one, the current through R_1 will:



a) Decrease.

b) Increase.

c) Remain the same.

d) It is impossible to say without knowing the values of R_1 and R_2.

9. An Ohm is equal to:

a) $1\,\frac{\mathrm{V}}{\mathrm{A}}$

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

c) $1\,\mathrm{V}\cdot\mathrm{A}$

d) $1\,\mathrm{W}\cdot\mathrm{A}$

10. A $2.0\,\Omega$ resistor carries a current of $1.0\,\mathrm{A}$ for one minute. What is the total energy dissipated?

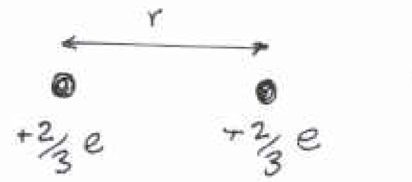
a) $4.0\,\mathrm{J}$

b) $60.0\,\mathrm{J}$

c) $120\,\mathrm{J}$

d) $240\,\mathrm{J}$

Problems



1. Inside a proton, we find quarks which have a charge of $+2e/3$. Suppose two of these quarks are separated by 1.0×10^{-15} m.

a) What is the magnitude of the repulsive force between these particles? (5)

$r = 1.0 \times 10^{-15}\ m$

From Coulomb's law, repulsive force is

$$F = k\frac{|q_1 q_2|}{r^2} = \left(8.99\times10^{9}\,\frac{Nm^2}{C^2}\right)\frac{(\frac{2}{3})(1.602\times10^{-19}C)(\frac{2}{3})(1.609\times10^{-19}C)}{(1.0\times10^{-15}\,m)^2}$$

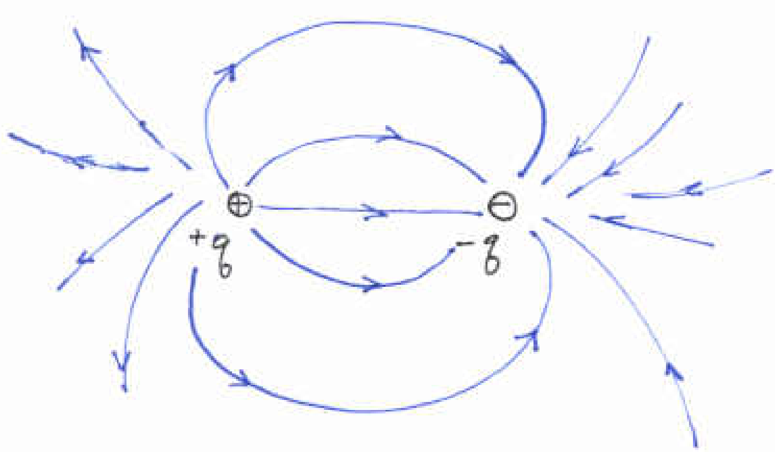
$$= \boxed{103\ N}$$

b) What is the potential energy of this pair of charges? Give the answer in eV's (6)

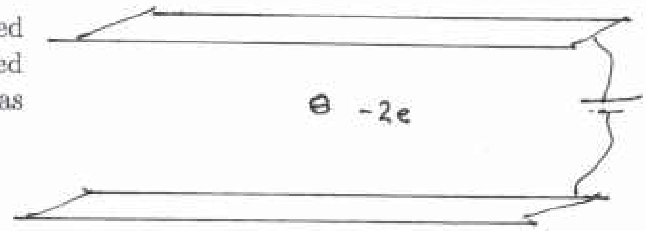
$$EPE = k\frac{q_1 q_2}{r} = (8.99\times10^{9})\frac{(\frac{2}{3})(1.602\times10^{-19}\,C)(\frac{2}{3})(1.602\times10^{-19}\,C)}{(1.0\times10^{-15}\,m)}$$

$$= 1.02\times10^{-13}J\left(\frac{eV}{1.602\times10^{-19}J}\right) = \boxed{6.4\times10^{5}\,eV}$$

2. Two charges $+q$ and $-q$ (shown below) form a dipole; for this configuration of charges, draw the electric field lines. (Show the shape of the lines and their directions.) (4)



3. A small charged particle with a charge of $-2e$ is suspended (i.e. supported against its weight) in a uniform E field created by two large charged parallel plates. The electric field has magnitude $9000\ \frac{\mathrm{N}}{\mathrm{C}}$.

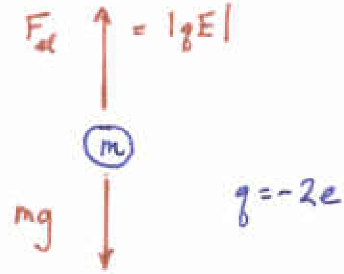


a) Does the $\mathbf{E}$ field point up or down? (2)

$\vec{F}_{el} = q\vec{E}$ and $\vec{F}_{el}$ points up and q is negative.

The $\vec{E}$ field points $\boxed{\text{down.}}$

b) What is the magnitude of the electric force on the particle? (5)



Upward elec. force on particle has magnitude

$$F_{elec} = |qE| = (2e)(9000\ ^{N}/_{C})$$

$$= 2(1.602\times10^{-19}\,C)(9000\,\tfrac{N}{C}) = \boxed{2.88\times10^{-15}\,N}$$

c) What is the mass of the particle? (5)

The forces balance: $F_{elec} = mg$, so:

$$m = \frac{F_{elec}}{g} = \frac{2.88\times10^{-15}\,N}{9.8\,^{m}/_{s^2}} = \boxed{2.94\times10^{-16}\,kg}$$

d) If the plates are separated by 0.800 cm what is the potential difference (voltage) between the plates? (4)

$|\Delta V| = |E\,\Delta x|$ since the field between the plates is uniform.

So:

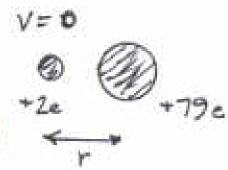
$$|\Delta V| = (9000\,\tfrac{N}{C})(0.800\times10^{-2}\,m)$$

$$= \boxed{72\ \text{Volts}}$$

4. A particle with a charge of $+2e$ ad a mass of 6.70×10^{-27} kg has a speed v_0 when it is far away from a very massive particle with charge $+79e$.

The particle flies straight toward the big charge and momentarily stops when it is 1.2×10^{-14} m from it.

a) What is the potential energy of the system when the charge is at the near position? (5)



Potential energy of the two charges is then

$$EPE = k\frac{q_1 q_2}{r} = \left(8.99\times10^{9}\ \frac{N\cdot m^2}{C^2}\right)\frac{(2)(1.602\times10^{-19}\,C)(79)(1.602\times10^{-19}\,C)}{(1.2\times10^{-14}\,m)}$$

$$= \boxed{3.04\times10^{-12}\ J}$$

b) What was the speed of the particle when it was far away? (Hint: At a very large distance, the potential energy is zero, and *total* energy is conserved.) (6)

Energy found in (a) was the original KE of the particle.

So $\frac{1}{2} m v_0^2 = 3.04\times10^{-12}$ J, and:

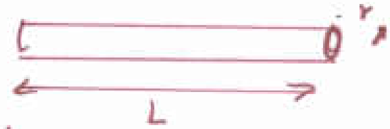
$$v_0^2 = \frac{2(3.04\times10^{-12}\,J)}{m} = \frac{2(3.04\times10^{-12}\,J)}{(6.70\times10^{-27}\,kg)}$$

$$= 9.07\times10^{14}\ \frac{m^2}{s^2}$$

$$\Rightarrow \quad v_0 = \boxed{3.01\times10^{7}\ \frac{m}{s}}$$

5. A length of copper wire has a circular cross section with diameter 3.0 mm. The length of the wire is 1.00 km. What is the resistance of the wire?

You may need the fact that $\rho_{\text{copper}} = 1.72 \times 10^{-8}\,\Omega \cdot \text{m}$ (6)



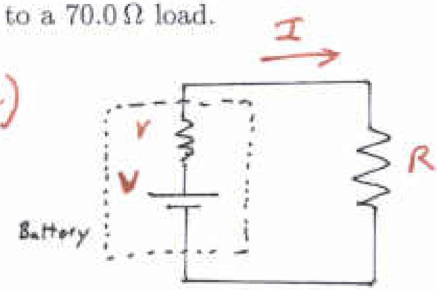
Cross-sec area of wire is, with $r = 1.5 \times 10^{-3}$ m

$A = \pi r^2 = 7.07 \times 10^{-6}\,\text{m}^2$. Then the resistance is:

$$R = \rho \frac{L}{A} = (1.72 \times 10^{-8}\,\Omega \cdot \text{m}) \frac{(1.00 \times 10^{3}\,\text{m})}{(7.07 \times 10^{-6}\,\text{m}^2)} = \boxed{2.43\,\Omega}$$

6. A battery having an emf of 13.0 V delivers 100 mA when connected to a 70.0 Ω load.

Find the internal resistance of the battery. (7)



Equiv. resistance of circuit is $(r + R) = (r + 70.0\,\Omega)$

so by Ohm's law we have:

$I = 100$ mA

$V = 13.0$ V

$$V = I\,(r + 70.0\,\Omega)$$

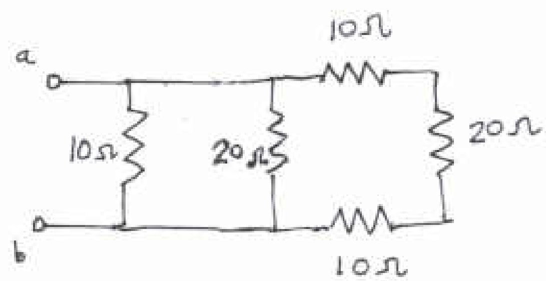
$$r + 70.0\,\Omega = V/I = \frac{13.0\text{ V}}{(100 \times 10^{-3}\text{ A})}$$

$$= 130\,\Omega$$

$$\rightarrow \boxed{r = 60\,\Omega}$$

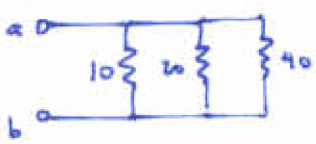
7. A set of 10.0 Ω and 20.0 Ω resistors is connected in the configuration shown at the right.

What is the equivalent resistance between points a and b? (7)



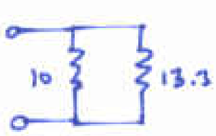
Combine end resistors (series) to single

40Ω resistor:



Combine 40Ω in parallel w/ 20Ω as $R_{eq} = \left(\frac{1}{20} + \frac{1}{40}\right)^{-1} = 13.3\,\Omega$

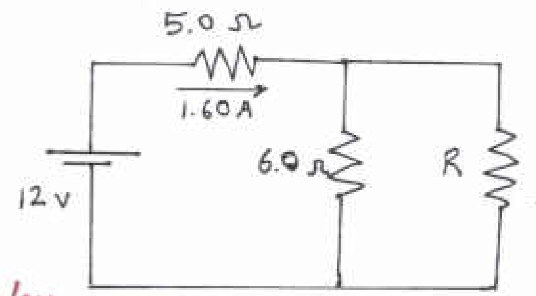
Get:



Combine 10 Ω in parallel w/ 13.3 Ω to get

$$R_{\text{equiv}} = \left(\frac{1}{10} + \frac{1}{13.3}\right)^{-1} = \boxed{5.7\,\Omega}$$

8. In the circuit shown at the right, three resistors are connected as shown to a 12.0 V battery. The current through the 5.0 Ω resistor is 1.6 A.



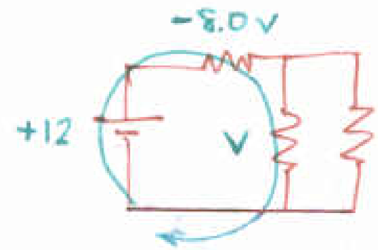
a) What is the potential difference across the 5.0 Ω resistor? (3)

Current in this resistor is 1.60 A, so by Ohm's law,

$$V = IR = (1.60\,A)(5.0\,\Omega) = \boxed{8.0\,V}$$

b) What is the potential difference across the 6.0 Ω resistor? (4)

Considering the left loop the Kirchhoff loop says the potential diff across this resistor must be $\boxed{4.0\,V}$

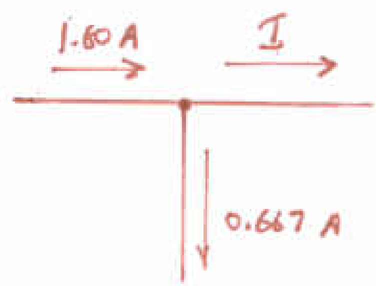


c) What is the current through the 6.0 Ω resistor? (3)

We know the voltage across this resistor; Ohm's law gives

$$I = V/R = \frac{4.0\,V}{6.0\,\Omega} = \boxed{0.667\,A}$$

d) What is the current through resistor R? (3)



Using the junction rule for the top junction we see:

$$1.60\,A = 0.667\,A + I, \quad \text{so}$$

$$I = \boxed{0.933\,A}$$

e) What is the value of R? (5)

The voltage across R is <u>also</u> 4.0 V, same as the 6.0 Ω resistor. The current thru it is 0.933 A. Then from Ohm's Law,

$$R = V/I = 4.0V/0.933A = \boxed{4.3\,\Omega}$$