Useful Constants

\[ \begin{align*}
  k_e &= 8.99 \times 10^9 \text{ N m}^2/\text{C}^2 \\
  \varepsilon_0 &= 8.85 \times 10^{-12} \text{ C}^2/(\text{N m}^2) \\
  G &= 6.673 \times 10^{-11} \text{ N m}^2/\text{kg}^2 \\
  e &= 1.602 \times 10^{-19} \text{ C} \\
  m_p &= 1.672 \times 10^{-27} \text{ kg} \\
  m_e &= 9.110 \times 10^{-31} \text{ kg} \\
  c &= 3.00 \times 10^8 \text{ m/s} \\
  g &= 9.80 \text{ m/s}^2 \\
  1 \text{ eV} &= 1.602 \times 10^{-19} \text{ J} \\
  1 \text{ mA} &= 10^{-3} \text{ A} \\
  1 \text{ \mu} &= 1 \text{ micro} = 10^{-6} \\
  1 \text{ k}\Omega &= 10^3 \Omega \\
  1 \text{ \muF} &= 10^{-6} \text{ F} \\
  1 \text{ km} &= 10^3 \text{ m} \\
  1 \text{ mm} &= 10^{-3} \text{ m} \\
  1 \text{ min} &= 60 \text{ s} \\
  1 \text{ hr} &= 3600 \text{ s} 
\end{align*} \]
Useful Formulae

\[ A \text{ (circle)} = \pi r^2 = \pi D^2/4 \]
\[ A \text{ (sphere)} = 4\pi r^2 = \pi D^2 \]
\[ \sin \theta = \text{(opposite)}/(\text{hypotenuse}) \]
\[ \cos \theta = \text{(adjacent)}/(\text{hypotenuse}) \]
\[ \tan \theta = \sin \theta / \cos \theta = \text{(opposite)}/(\text{adjacent}) \]
\[ \Sigma \vec{F} = m\vec{a} \]
\[ KE = \frac{1}{2}mv^2 \]
\[ F_e = k_e|q_1||q_2|/r^2 \]
\[ \Phi_E = \vec{E} \cdot \vec{A} = EA \cos \theta = Q_{\text{inside}}/\varepsilon_0 \]
\[ P = W/\Delta t = I \Delta V = I^2 R = (\Delta V)^2/R \]
\[ Q_{\text{tot}} = Nq \]
\[ W = \Delta PE = \pm q \Delta V = \pm q E d \]
\[ R = \rho L/A \]
\[ R = R_0[1 + \alpha(T - T_0)] \]
\[ C = Q/\Delta V \]
\[ C_0 = \varepsilon_0 A/d \]
\[ U = Q^2/(2C) = \frac{1}{2}C(\Delta V)^2 = \frac{1}{2}Q(\Delta V) \]
\[ r^2 = x^2 + y^2 \]
\[ 1 = \cos^2 \theta + \sin^2 \theta \]
\[ \vec{F}_g = \vec{w} = m\vec{g} \]
\[ \Delta PE = q \Delta V \]
\[ \vec{E} = \vec{F}_e/q \]
\[ E = k_e|q|/r^2, \quad \vec{E}_{\text{tot}} = \Sigma \vec{E}_i \]
\[ V = k_e q/r \]
\[ \Delta V = \pm E d \]
\[ V = \Sigma V_i = k_e \Sigma (q_i/r_i) \]
\[ R = \Delta V/I \]
\[ \rho = \rho_0[1 + \alpha(T - T_0)] \]
\[ I = \Delta Q/\Delta t \]
\[ C = \kappa C_0 \]
\[ \Delta V = \pm E d \]
1. A conductor has $1.24 \times 10^7$ free electrons distributed around the surface of this object. What is the total charge of this object?
   a) $-1.99 \times 10^{-12} \text{ C}$  b) $1.60 \times 10^{-19} \text{ C}$  c) $-1.24 \times 10^7 \text{ C}$  
d) $-3.14 \times 10^6 \text{ C}$  e) $0.00 \text{ C}$

2. What electric force does the electron ($q = -e$) feel from the proton ($q = +e$) in the ground state of hydrogen? The radius of the ground state of hydrogen is $5.29 \times 10^{-11} \text{ m}$.
   a) $2.57 \times 10^{-38} \text{ N}$  b) $1.60 \times 10^{-19} \text{ N}$  c) $9.17 \times 10^{-18} \text{ N}$
   d) $8.24 \times 10^{-8} \text{ N}$  e) $1.44 \times 10^{-6} \text{ N}$

3. A 1.62 k$\Omega$ resistor is connected to a battery and has 2.24 mA of current flowing through it. What is the potential difference across the terminals of the battery?
   a) 0.723 V  b) 1.38 V  c) 3.63 V  d) 12.0 V  e) 120 V

4. A fully charged capacitor contains 9890 J of energy. If the negative side of the capacitor has $2.27 \times 10^{18}$ electrons on its plate, what is the capacitance of this capacitor? (*Hint: Each electron has $|q| = e.$*)
   a) 4.36 kF  b) $2.29 \times 10^5 \text{ F}$  c) 6.69 $\mu$F  d) 9.89 pF  e) 2.27 mF

5. A 200 W light bulb is plugged into a 120 V outlet. How long will this bulb have to shine to produce $3.20 \times 10^4 \text{ J}$ of energy? (*Hint: Remember that work is a form of energy.*)
   a) $3.20 \times 10^4 \text{ s}$  b) 1.67 s  c) 0.60 hr  d) 200 hr  e) 2.67 min
Part B: Easy Multiple Choice (10 points total, 1 point each, Circle Best Answer).

6. Which of the following is not true about Coulomb’s force law?

a) It is a field force law.
b) It obeys the principle of superposition.
c) It describes the strength of the gravitational force.
d) It describes the strength of the electric force.
e) It is an inverse-square law.

7. The quantity of electrical potential, the volt, is dimensionally equivalent to:

a) force $\times$ charge  
b) force/charge  
c) electric field/distance  
d) electric field $\times$ distance  
e) none of these

8. Which of the following is true concerning a uniformly charged conducting hollow metallic sphere in electrostatic equilibrium?

a) The electric field strength increases with distance from the sphere.
b) The electric field lines follow circular paths parallel to the surface.
c) The potential would be constant in all regions of space outside the sphere.
d) The potential is zero everywhere inside the conductor.
e) The electric field is zero everywhere inside the conductor.

9. Who was the first to determine the electron’s charge?

a) Newton  
b) Franklin  
c) Ohm  
d) Millikan  
e) Coulomb

10. Which of the following has zero internal resistance?

a) air  
b) superconductor  
c) copper wire  
d) gold wire  
e) plastic
11. In the equation, \( R = \frac{\rho L}{A} \), ‘\( \rho \)’ represents:
   a) inductance  b) capacitance  c) resistance  
   d) resistivity  e) mass density

12. There are 4206 electric field lines going perpendicularly through a square centimeter of area. This is a statement of:
   a) electric flux  b) electric current  c) electric potential  
   d) capacitance  e) electric resistance

13. Which of the following units measure energy?
   a) kWh  b) m/s  c) dyne/m  d) tesla  e) N

14. What two measurements are needed to measure the capacitance of a capacitor?
   a) resistance & charge  b) resistance & current  c) charge & current  
   d) potential difference & charge  e) inductance & current

15. Which of the following is true concerning the velocity of electrons in a circuit?
   a) Electrons move faster in an insulator than in a conductor.  
   b) Electrons don’t move in a conductor, just the E-field moves.  
   c) Electrons travel at the speed of light in a conductor, but slower in an insulator.  
   d) Electrons move in the direction of the electric field in a conductor.  
   e) None of these are true.
Part C: Problems (20 points total, 10 points each).

16. Three charges are aligned on the $x$-axis. Charge $q_1 = 6.44 \times 10^{-10}$ C sits at $x_1 = -15.2$ cm, charge $q_2 = -2.84 \times 10^{-11}$ C sits at $x_2 = +6.24$ cm, and charge $q_3 = 6.67 \times 10^{-9}$ C sits at $x_3 = +17.6$ cm. Calculate the total electric field at point $P$ which lies on the origin. (*Hint:* The positive direction is to the right and the negative direction to the left. Make sure your units are consistent! **Show all work including units and diagram!**)
17. A fully charged capacitor stores $7.40 \times 10^{-10}$ J of energy while connected to a 8.00 V battery. 

(a) If this capacitor has circular plates of radius 2.78 cm, what must be the separation between these two plates (in mm)? 

(b) How much charge is on these plates? (Show all work including units and unit conversions!)
Extra Credit Problem (5 points, do this only if you have time).

18. An uniform electric field passes through a plane surface that is 1.64 m wide and 3.22 m high. This electric field is passing through this surface at an angle of 36.2° with respect to the normal of this surface. If this electric field has a flux of $6.78 \times 10^3$ N·m²/C through this surface, what is the strength of the electric field? (Show all work including figure!)