PHYSICS 112 - REVIEW FOR EXAM 1

ELECTRIC CHARGES

Electric charges are positive, negative, or zero; they are measured in coulombs (symbol: C). Electric charges are quantized: every object in the universe has a electric charge $q = \pm ne$, where $n = 0, 1, 2, \ldots$ is an integer and $e = -1.6 \times 10^{-19}$ C. Electrons, neutrons, and protons have charges $-e, 0, +e$, respectively. Electrical and magnetic forces act on charged particles.

ELECTRIC FORCES

Coulomb's law: The electric force beween two particles of electric charge q_1 and q_2 separated by a distance r has magnitude $F = \frac{k_e |q_1||q_2|}{r^2}$, where $k = 9 \times 10^9$ N-m^2/C^2 is a universal constant.

The forces on two positive or two negative charges is repulsive, directly straight away from each other. The forces between a positive and a negative charge are attractive, directed towards each other.

ELECTRIC FIELDS

The **electric field $\vec{E}$** at a point where the electric force on a small charge q (positive or negative) is $\vec{F}$ is given by $\vec{E} = \frac{\vec{F}}{q}$. The electric field has units of N/C. Consequently, the force on a charge in an electric field is $\vec{F} = q\vec{E}$. The electric force on a positive charge is in the direction of the electric field; the electric force on a negative charge is opposite to the direction of the electric field.

The electric field due to a charge Q at a distance r from the charge has magnitude $|\vec{E}| = \frac{k_e|Q|}{r^2}$ and is directed straight away from a positive charge and straight towards a negative charge.

The electric field at a general point can be determined by the Principle of Superposition, by adding the electric field vectors at that point due to all the charges in the universe. The electric field in space can be represented by electric field lines.

ELECTRIC POTENTIAL ENERGY

Energy formulas from Physics 111: Kinetic energy: $KE = \frac{1}{2}mv^2$.

Work: $W = Fd\cos\theta$ (in terms of a force and a displacement)

Total work: $W_{\text{total}} = W_c + W_{nc}$ (work by conservative forces + work by nonconservative forces)

Work by a conservative force: $W_c = -\Delta PE$.

Work-energy theorem: $W_{\text{total}} = \Delta KE$.

Mechanical energy: $TE = KE + PE$. $\Delta TE = \Delta KE + \Delta PE = W_{\text{total}} - W_c = W_{nc}$

The **electric potential energy** of a system of two charges q_1 and q_2 a distance r apart is $PE = \frac{kq_1q_2}{r}$ (note the single power of r in the denominator). Like any energy, it is measured in joules (J). This is positive if the two charges have the same sign and is negative if they have opposite signs.

The electric potential energy of a system of many charges is the sum of the two-charge electric potential energies of each pair of charges. (Count each pair once: For 3 particles, use terms for 1 & 2, 1 & 3 and 2 & 3.)

ELECTRIC POTENTIAL: Electric potential V is defined as the potential energy per charge: $V = \frac{PE(q)}{q}$ is the electric potential at a certain point, where $PE(q)$ is the electric potential energy added to the system when a small charge q is placed at that point. The unit of electric potential is the J/C or V (volt).

The electric potential at a distance r from a point charge q is $V = kq/r$, which can be positive or negative depending on the sign of q. The Principle of Superposition applied to electric potential: V at a point in space is the sum of the electric potentials at that point due to all the charges in the universe.

The change in the electric potential energy of a system when a charge q is moved from an initial point (i) to a final point (f) is $\Delta PE = q\Delta V = q(V_f - V_i)$. The sign of the change in electric potential energy depends on the signs of q and of ΔV, and can be positive or negative.

An equipotential surface is one on which the electric potential is a constant; equipotential surfaces are perpendicular to electric field lines.

Capacitance: Capacitance C is defined by $Q = C\,\Delta V$. Energy stored is $\frac{1}{2}C(\Delta V)^2$.