PHYS 1441 – Section 002
Lecture #9

Monday, Oct. 1, 2018

Dr. Jaehoon Yu

- Chapter 23 Electric Potential
  - Equi-potential Lines and Surfaces
  - Electric Potential Due to Electric Dipole
  - Electrostatic Potential Energy
- Chapter 24 Capacitance etc..
  - Capacitors

Today's homework is homework #6, due 11pm, Monday, Oct. 8!!

Announcements

- Bring out your special project #3
- Colloquium 4pm this Wednesday, Oct. 3, SH101
  - Dr. Xi Zhang of U.C. Santa Cruz

Physic Department
The University of Texas at Arlington
COLLOQUIUM

Physics of Hazes and Clouds in Cold and Hot Planetary Atmospheres

Xi Zhang
University of California Santa Cruz

Wednesday October 3, 2018
4:00 p.m. Room 100 Science Hall

Abstract

Hazes and clouds are ubiquitous in all substantial atmospheres in the solar system. Abundant condensed particles are also inferred from the transmission observations in the warm and hot (500-2200 K) atmospheres of extra-solar planets which are hundreds to thousands of degrees warmer than the solar system planets. These exotic clouds could result from condensation of salts, silicates and metals, and/or hydrocarbons produced by atmospheric photochemistry and ion chemistry. In this presentation, I will first talk about the thin, cold and hazy atmospheres in the outer solar system such as on Saturn's moon Titan, Neptune's moon Triton, and Pluto. I will present how these atmospheres regulate themselves such that the chemical-produced hydrocarbon haze particles significantly dominate the radiative energy balance over the gas volatiles. In particular, the haze particles could explain the colder-than-expected temperature on Pluto observed by the New Horizons mission recently. Then I will talk about the thick, hot and cloudy atmospheres of hot Jupiters and brown dwarf stars. I will show how to form clouds of salts, silicates and metals in this regime, highlighting the important physical processes such as seed formation, nucleation, coagulation, condensation, gravitational settling as well as atmospheric particle transport. I will also emphasize the importance of particle size distribution on interpreting the observed transmission spectra of extra-solar planets and how to predict it from first principles in a self-consistent microphysical cloud formation model.

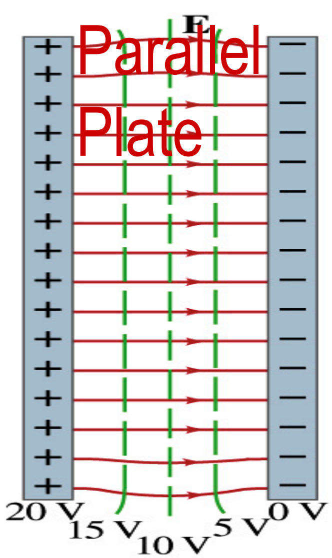
Refreshments will be served at 3:30 in Physics Lounge.

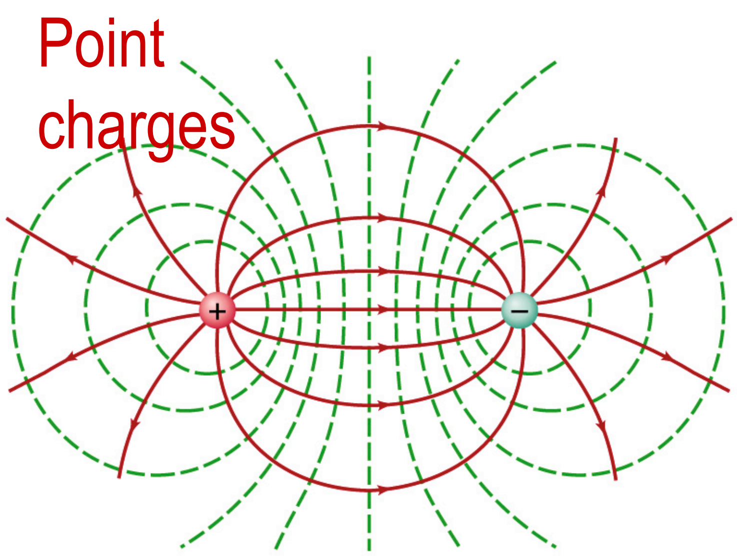
Equi-potential Surfaces

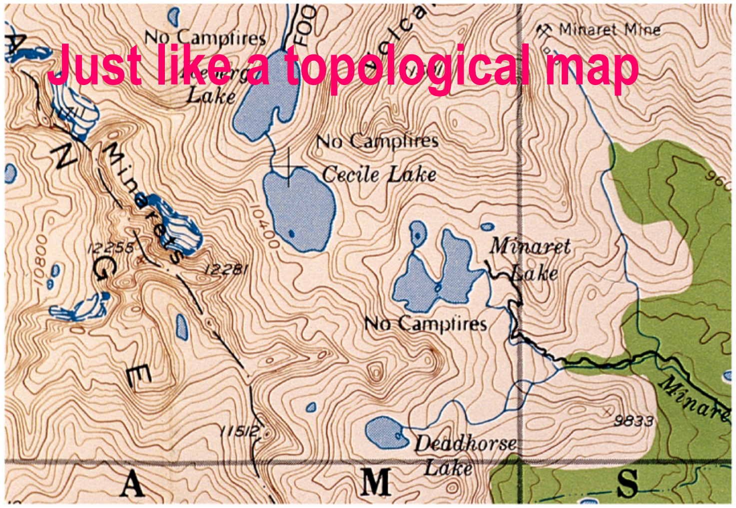
- Electric potential can be graphically shown using the equipotential lines in 2-D or the equipotential surfaces in 3-D
- Any two points on the equipotential surfaces (lines) are at the same potential
- What does this mean in terms of the potential difference?
  - The potential difference between any two points on an equipotential surface is 0.
- How about the potential energy difference?
  - Also 0.
- What does this mean in terms of the work to move a charge along the surface between these two points?
  - No work is necessary to move a charge between these two points.

Equi-potential Surfaces

- An equipotential surface (line) must be perpendicular to the electric field. Why?
  - If there are any parallel components to the electric field, it would require work to move a charge along the surface.
- Since the equipotential surface (line) is perpendicular to the electric field, we can draw these surfaces or lines easily.
- Since there can be no electric field within a conductor in a static case, the entire volume of a solid conductor must be at the same potential.
- So the electric field must be perpendicular to the conductor surface.

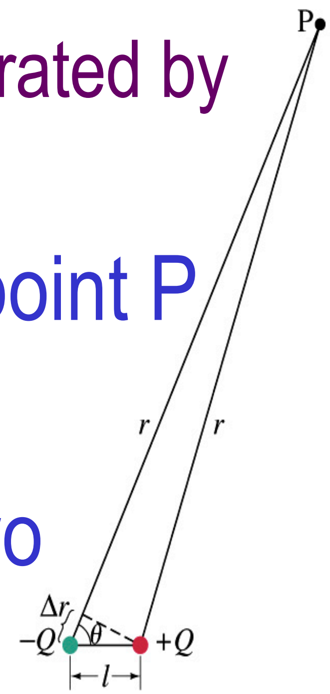






Electric Potential due to Electric Dipoles

- What is an electric dipole?
  - Two equal point charge Q of opposite signs separated by a distance ℓ and behaves like one entity: $p=Q\ell$
- For the electric potential due to a dipole at a point P
  - We take V=0 at r=∞
- The simple sum of the potential at P by the two charges is



$$V=\sum\frac{Q_i}{4\pi\varepsilon_0}\frac{1}{r_{ia}}=\frac{1}{4\pi\varepsilon_0}\left(\frac{Q}{r}+\frac{(-Q)}{r+\Delta r}\right)=\frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{r}-\frac{1}{r+\Delta r}\right)=\frac{Q}{4\pi\varepsilon_0}\frac{\Delta r}{r(r+\Delta r)}$$

- Since $\Delta r=\ell\cos\theta$ and if $r\gg\ell$, $r\gg\Delta r$, thus $r\sim r+\Delta r$ and

$$V=\frac{Q}{4\pi\varepsilon_0}\frac{l\cos\theta}{r^2}=\frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2}$$

V by a dipole at a distance r from the dipole

$$\boxed{V=\frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2}}$$

E Determined from V

- Potential difference between two points under an electric field is $V_b - V_a = -\int_a^b \vec{E} \cdot d\vec{l}$
- So in a differential form, we can write

$$dV = -\vec{E} \cdot d\vec{l} = -E_l dl$$

  – What are dV and E_ℓ?
    - dV is the infinitesimal potential difference between the two points separated by a distance $d\ell$
    - E_ℓ is the field component along the direction of $d\ell$.
- Thus we can write the field component E_ℓ as

$$E_l = -\frac{dV}{dl}$$

Physical Meaning?

The component of the electric field in any direction is equal to the negative rate of change of the electric potential as a function of distance in that direction.!!

E Determined from V

- The quantity $dV/d\ell$ is called the **gradient of V** in a particular direction
  - If no direction is specified, the term gradient refers to the direction on which **V changes most rapidly** and this would be the direction of the field vector **E** at that point.
  - So if **E** and $d\ell$ are parallel to each other, $E = -\frac{dV}{dl}$
- If E is written as a function x, y and z, the ℓ refers to x, y and z $E_x = -\frac{\partial V}{\partial x}$ $E_y = -\frac{\partial V}{\partial y}$ $E_z = -\frac{\partial V}{\partial z}$
- $\frac{\partial V}{\partial x}$ is the "partial derivative" of V with respect to x, while y and z are held constant
- In vector form, $\vec{E} = -gradV = -\vec{\nabla} V = -\left(\vec{i}\frac{\partial}{\partial x} + \vec{j}\frac{\partial}{\partial y} + \vec{k}\frac{\partial}{\partial z}\right)V$

$\vec{\nabla} = -\left(\vec{i}\frac{\partial}{\partial x} + \vec{j}\frac{\partial}{\partial y} + \vec{k}\frac{\partial}{\partial z}\right)$ is called *del* or the *gradient operator* and is a *vector operator*.

Electrostatic Potential Energy

- Consider a case in which a point charge q is moved between points *a* and *b* where the electrostatic potential due to other charges in the system is V_a and V_b
- The change in electrostatic potential energy of q in the field by other charges is

$$\Delta U = U_b - U_a = q\left(V_b - V_a\right) = qV_{ba}$$

- Now what is the electrostatic potential energy of a system of charges?
  - Let's choose V=0 at r=∞
  - If there are no other charges around, single point charge Q_1 in isolation has no potential energy and is under no electric force

Electrostatic Potential Energy; Two charges

- If a second point charge Q_2 is brought close to Q_1 at a distance r_{12}, the potential due to Q_1 at the position of Q_2 is

$$V = \frac{Q_1}{4\pi\varepsilon_0}\frac{1}{r_{12}}$$

- The potential energy of the two charges relative to V=0 at r= ∞ is

$$U = Q_2 V = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r_{12}}$$

  - This is the work that needs to be done by an external force to bring Q_2 from infinity to the distance r_{12} from Q_1.
  - It is also a negative of the work needed to separate them to infinity.

Electrostatic Potential Energy; Three Charges

- So what do we do for three charges?
- Work is needed to bring all three charges together
  - Work needed to bring Q_1 to a certain location without the presence of any charge is 0.
  - Work needed to bring Q_2 to a distance to Q_1 is $U_{12} = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r_{12}}$
  - Work need to bring Q_3 to certain distances to Q_1 and Q_2 is

$$U_3 = U_{13} + U_{23} = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_3}{r_{13}} + \frac{1}{4\pi\varepsilon_0}\frac{Q_2 Q_3}{r_{23}}$$

- So the total electrostatic potential energy of the three charge system is

$$U = U_{12} + U_{13} + U_{23} = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q_1 Q_2}{r_{12}} + \frac{Q_1 Q_3}{r_{13}} + \frac{Q_2 Q_3}{r_{23}}\right) \quad \left[V = 0 \text{ at } r = \infty\right]$$

  - What about a four charge system or N charge system?

Electrostatic Potential Energy: electron Volt

- What is the unit of electrostatic potential energy?
  - Joules
- Joules is a very large unit in dealing with electrons, atoms or molecules atomic scale problems
- For convenience a new unit, electron volt (eV), is defined
  - 1 eV is defined as the energy acquired by a particle carrying the magnitude of the charge equal to that of an electron (q=e) when it moves across a potential difference of 1V.
  - How many Joules is 1 eV then? $1eV = 1.6\times10^{-19}C\cdot 1V = 1.6\times10^{-19}J$
- eV however is **<u>NOT a standard SI unit</u>**. You must convert the energy to Joules for computations.
- What is the speed of an electron with kinetic energy 5000eV?