PHY 114 A General Physics II
11 AM-12:15 PM TR Olin 101

Plan for Lecture 5:

1. More about electrostatic potentials
2. Review of Electrostatics (Chapters 23-25)
3. Advice about preparing/taking physics exams.

Announcements:

i-clicker question
Would you attend a review session for next Tuesday’s exam on:
A. Sunday afternoon at 3 PM
B. Monday afternoon at 4 PM
C. Would like a review session at a different time.
D. Would not/could not attend a review session at any time.
More about electric potentials:

Electrical ground

\[ V = 0 \]

The symbol \( \equiv \) implies that the “grounded” object is supplied with any necessary charge to maintain voltage \( V = 0 \).

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Millikan oil drop experiment

Equilibrium condition: \( qE = mg \)

If \( E \) and \( m \) are known, \( q \) is measured by the experiment. It is reasonable to assume that \( q = -Ne \).

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Van de Graaff generator

Uniformly charged spherical shell

\[ E = \frac{kQ}{r^2} \]
\[ V = \frac{kQ}{r} \]

Strong fields can break chemical bonds as does lightning.
Electrostatic potential due to continuous charge distributions

- Can determine potential from electric field according to

\[ V = -\int E \cdot ds \]

- Can perform integral over charge distribution directly

\[ E(r) = k \sum_j \frac{q_j}{|r - r_j|^3} |r - r_j| \]
\[ V(r) = k \sum_j \frac{q_j}{|r - r_j|} = k \int \frac{dq(r')}{|r - r'|} \]

Example – consider a long thin uniformly charged rod:

\[ dq = \frac{Q}{2L} \, dx \]
\[ E_x = k \int \frac{y \, dq}{(x^2 + y^2)^{3/2}} = \frac{kQ}{2L} \int \frac{dx}{(x^2 + y^2)^{3/2}} = \frac{kQ}{2L} \ln \left( \frac{x + \sqrt{x^2 + y^2}}{x - \sqrt{x^2 + y^2}} \right) = \frac{kQ}{2L} \ln \left( \frac{L + \sqrt{L^2 + y^2}}{-L + \sqrt{L^2 + y^2}} \right) \]
\[ E_y = \frac{dV}{dy} \]

i-clicker question:
Consider the distribution of charges shown below. Which of the following statements is most accurate.

A. This charge distribution was introduced by evil physics professor to torture their students.
B. This charge distribution is stable with no additional forces.
C. The charge distribution can be stable only with additional forces.
Reminder:

1. First exam – Tuesday, February 6, 2012
   – covering Chapters 23-25.
   - 5 problems – show your work and reasoning for possible partial credit.
   - Should bring 1 8½” x 11” sheet of paper to the exam (to be turned in with your exam papers).
   - Should bring calculator for numerical work. Must not use cell phones or computers during the exam.

Advice:

1. Keep basic concepts and equations at the top of your head.
2. Practice problem solving and math skills
3. Develop an equation sheet that you can consult.

Problem solving steps

1. Visualize problem – labeling variables
2. Determine which basic physical principle(s) apply
3. Write down the appropriate equations using the variables defined in step 1.
4. Check whether you have the correct amount of information to solve the problem (same number of knowns and unknowns).
5. Solve the equations.
6. Check whether your answer makes sense (units, order of magnitude, etc.).
Example problem:
Consider the following configuration of point charges
$q_1 = 2 \mu C$ and $q_2 = 4 \mu C$ as shown. Determine the electric field $E$ at the position (in meters) $r = 2\hat{i} + 3\hat{j}$.

\[ E = \frac{kq_1(x_1\hat{i} + y_1\hat{j})}{(x_1^2 + y_1^2)^{3/2}} + \frac{kq_2(x_2\hat{i} + y_2\hat{j})}{(x_2^2 + y_2^2)^{3/2}} \]

\[ V = \frac{kq_1}{(x_1^2 + y_1^2)^{3/2}} + \frac{kq_2}{(x_2^2 + y_2^2)^{3/2}} \]
Example: An electron enters the region of a uniform electric field \( E = 200 \, \text{N/C} \) as shown with \( v_i = 3 \times 10^6 \, \text{m/s} \). The horizontal length of the plates is \( l = 0.1 \, \text{m} \). Find the vertical displacement \( y \) of the electron as it leaves the plates. (Ignore any field fringing effects.)

\[
y = \frac{1}{2} m \left( \frac{E}{v_i} \right) \cdot \left( \frac{1}{3 \times 10^8} \right)
\]

\[
= \frac{1.6 \times 10^{-19}}{2} \cdot \frac{200}{9.1 \times 10^{-31}} \left( \frac{0.1}{3 \times 10^8} \right)
\]

\[
y = 0.0195 \, \text{m}
\]

Integral-differential relationship between \( E \) and \( V \) in one dimension.

\[
E(x) = -\frac{dV(x)}{dx}
\]

\[
V(x) = -\int E(x')dx'
\]

For \( 0 \leq x \leq 1 \, \text{cm} \)
\[
\frac{dV(x)}{dx} = \frac{20}{0.01} \, \frac{\text{V}}{\text{m}} = 2000 \, \frac{\text{V}}{\text{m}}
\]

For \( 1 \leq x \leq 3 \, \text{cm} \)
\[
\frac{dV(x)}{dx} = 0 \, \frac{\text{V}}{\text{m}}
\]

For \( 3 \leq x \leq 4 \, \text{cm} \)
\[
\frac{dV(x)}{dx} = -\frac{20}{0.01} \, \frac{\text{V}}{\text{m}} = -2000 \, \frac{\text{V}}{\text{m}}
\]

Review question

The diagram below shows a point positive charge \( q \) placed at the center of an electrically isolated conducting shell. What is the magnitude of the field \( E \) measured at a radius \( r \) outside the shell?

A. \( E = 0 \)
B. \( E = k \frac{q}{r^2} \)
C. Not enough information to solve this problem
Review question

The diagram below shows a point positive charge $q$ placed at the center of an electrically grounded conducting shell. What is the magnitude of the field $E$ measured at a radius $r$ outside the shell?

A. $E=0$
B. $E=kq/r^2$
C. Not enough information to solve this problem

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Summary of electric fields and potentials for special charge distributions:

Point charge $q$ at the origin: $E(r) = \frac{kq}{r^2}$

Charge $q$ uniformly distributed on long wire $L \gg r$:

$r =$ perpendicular distance from center of wire: $E(r) = \frac{kq/L}{r}$

Charge $q$ uniformly distributed on flat plate $A \gg z$:

$z =$ perpendicular distance from center of plate: $E(z) = 2\piq/Az$

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