1. Check out the syllabus carefully: the schedule of lectures, quizzes and exams, the grading system, and the homework.

2. This is all also on the Physics 2140 web site.

3. Also be sure you know the time and place of your lab section.

4. Buy lab manual from UT store
Web site

<http://astro1.panet.utoledo.edu/~vkarpov/Physics-2140.html>
The Daily Quizzes

- Similar system as used in 2130.
- Daily quizzes... sometime
- Encourage attendance, interaction, feedback.
- Research shows these things are good!
Homework

• For tomorrow:
  – Ch. 21 Questions 1,2; Problems 2,7,13,65
What is physics?

- **The structure of the physical world.**
  - What basic units are things made of?
  - The fundamental particles
    - Quarks, leptons, gluons, photons, gravitons

- **The laws of nature.**
  - How do these basic units behave?
  - The fundamental interactions
    - Gravitational, Electromagnetic, Nuclear
This Semester: 4-week segments

1. Electric Charges and Fields
   Chs. 21-25

2. Electrodynamics
   Chs 26-32

3. Optics and Relativity
   Chs 33-37

4. Quantum Physics
   Chs 38-44
A World of Electric Charge

• The world is made of charged particles

• The common ones are
  – The proton: Charge $Q_p = +e$
  – The electron: Charge $Q_e = -e$
  – The neutron: Charge $Q_n = 0$

• There is also the photon:
  – Photons have zero charge, but they interact with the charges of the others.
Atoms

Electrons

Nucleus

Protons

Neutrons
Atomic number and mass number

- \( Z = \text{atomic number} = \text{no. of e’s} = \text{no. of p’s} \)
  (so \( Q=0 \) for a neutral atom)
- \( A = \text{mass number} \)
  = no. of protons + no. of neutrons
  \( (m_p = m_n >> m_e) \)
- \( N_A = \text{Avagadro’s number} = 6 \times 10^{23} \)
  (number of atoms in one \( \text{mole} \) )

\( N_A \) is defined so that the mass of \( N_A \) atoms is \( A \) grams
Example Two isotopes of uranium: 

\[ \text{U}_{235} \left( ^{235}\text{U}_{92} \right) \text{ has } Z=92, \ A=235 \]
\[ \text{ (92p’s, 92e’s, 143n’s) } \]

\[ \text{U}_{238} \left( ^{238}\text{U}_{92} \right) \text{ has } Z=92, \ A=238 \]
\[ \text{ (92p’s, 92e’s, 146n’s) } \]

Question: How many atoms in 1 kg of U\text{235}? 

Answer: One mole is 235 grams, so 1 kg is 1000/235 = 4.26 moles. The number of atoms in a mole is \( N_A = 6 \times 10^{23} \) so the answer is

\[ 4.26 \times 6 \times 10^{23} = 2.6 \times 10^{24} \text{ atoms} \]
Surface of a pure metal showing individual atoms.
Chapter 21

• Electric Charge
• Coulomb’s Law
• Review
  – Powers of Ten
  – Vector Calculations
  – Atoms and Electrons
I. Electric Charge

- Two kinds: positive and negative
- Matter is made of charged particles: protons, electrons, atoms, molecules
- Charge is *conserved* and *quantized*
- The elementary charge: $e = 1.6 \times 10^{-19} \text{ C.}$
- Electric current -- the rate of flow of charge
- Conducting and insulating materials
II. Coulomb’s Law

\[ F = k \frac{Q_1 Q_2}{r^2} \]

• Inverse square law, attraction and repulsion
• SI units: Coulomb and Ampere
• The Coulomb constant: \( k = 9 \times 10^9 \) SI units.
III. Vector notation

\[ \hat{r} = \frac{r}{r} \text{ unit vector} \]

\[ \vec{F} \parallel \hat{r} \]

\[ \vec{F} = F\hat{r} \]
III. Vector Notation

\[ \vec{F} = k \frac{Q_1 Q_2 \vec{r}}{r^3} = k \frac{Q_1 Q_2 \hat{r}}{r^2} \]

If two forces act on a body, then the net force is the vector sum:

\[ \vec{F} = \vec{F}_1 + \vec{F}_2 \]

BUT remember that the magnitudes may NOT add:

\[ \vec{A} = \vec{B} + \vec{C} \text{ does not mean that } A = B + C \]
Chapter 21 Homework

• Read Chapter 21
  • Note Checkpoints 3, 4
  • Do Questions 1, 2 – not graded
  • Do Problems 2, 7, 13, 65
Syllabus

• Does everyone have a syllabus?

• Do you know the time and place of your lab section?

• Any questions about the course?
Notes about quizzes and exams

• Do the powers of 10 in your head.
• Use only one or two significant figures – that’s enough to show you have the basic principles right.

For example \( k \approx 9 \times 10^9 \approx 10^{10} \) SI units
Example Problem

Two charges are separated by 3 meters. If each charge is 2 microcoulombs, what is the force by one charge on the other?

Solution

\[ Q = 2 \mu C = 2 \times 10^{-6} C \]

\[ F = k \frac{Q^2}{r^2} = \frac{9 \times 10^9 \times (2 \times 10^{-6})^2}{3^2} \]

\[ F = \frac{9 \times 4 \times 10^{-3}}{9} = 4 \times 10^{-3} N \]
Chapter 21: Charge and Coulomb’s Law

If you don’t yet have syllabus and homework schedules please pick them up now.

Better find on the web
Chapter 21 Homework

• Find 2140 homepage (physics.utoledo.edu)
• Read Chapter 21
  • Note Checkpoints 3,4
  • Do Questions 1,2
  • Do Problems 2, 7, 13, 65
I. Electric Charge

- Two kinds: positive and negative
- Matter is made of charged particles: protons, electrons, atoms, molecules
- Charge is conserved and quantized
- The elementary charge: \( e = 1.6 \times 10^{-19} \, \text{C} \)
- Electric current -- the rate of flow of charge
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II. Coulomb’s Law

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• SI units: Coulomb and Ampere
• The Coulomb constant: \( k = 9 \times 10^9 \) SI units.
III. Vector Notation

\[ \vec{F} = k \frac{Q_1 Q_2 \vec{r}}{r^3} = k \frac{Q_1 Q_2 \hat{r}}{r^2} \]

If two forces act on a body, then the net force is the vector sum:

\[ \vec{F} = \vec{F}_1 + \vec{F}_2 \]

BUT remember that the magnitudes may NOT add:

\[ \vec{A} = \vec{B} + \vec{C} \] does not mean that \( A = B + C \)
Notes about quizzes and exams

• Do the powers of 10 in your head.
• Use only one or two significant figures – that’s enough to show you have the basic principles right.

For example \[ k = 9 \times 10^9 \] SI units
The quantum of charge

The world is made of atoms, which are made of protons, neutrons and electrons.

- Proton has charge $+e$.
- Electron has charge $-e$.
- Neutron has charge 0.

Atom is mostly empty space.
Tiny nucleus contains protons, neutrons.

Fundamental quantum of charge: $e = 1.60 \times 10^{-19}$ C
Moving Charge

• I can charge an object by adding or removing electrons.
• When I comb my cat, I move electrons from the fur to the rubber comb, leaving the cat with a net positive charge, and the comb with a negative charge.
• *Charge conservation* means that, if both cat and comb were originally neutral, then

\[ Q_{\text{cat}} + Q_{\text{comb}} = 0 \]
Atomic number and mass number

- $Z = \text{atomic number} = \text{no. of e’s} = \text{no. of p’s}$
  (so $Q=0$ for a neutral atom)

- $A = \text{mass number}$
  $= \text{no. of protons} + \text{no. of neutrons}$
  $(m_p = m_n >> m_e)$

- $N_A = \text{Avagadro’s number} = 6 \times 10^{23}$
  (number of atoms in one mole)

$N_A$ is defined so that the mass of $N_A$ atoms is $A$ grams
Example  Two isotopes of uranium:

\[ \text{U}_{235} \ ({}^{235}\text{U}_{92}) \ 	ext{has} \ Z=92, \ A=235 \]
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\[ 4.26 \times 6 \times 10^{23} = 2.6 \times 10^{24} \ 	ext{atoms} \]
Another example

• Estimate the force on a person who lost electrons from 1 gram of his/her body?

• Model body with a ~1 m$^3$ water sphere,

• 1 mole of H$_2$O is 18g.

• 1 g has $n=N_A/18 \sim 10^{22}$ atoms

• Electric charge $Q=ne \sim 10^3$ C

• Force $F=kQ^2/r^2 \sim 10^{10} \times (10^3)^2 / 1^2 = 10^{16}$ N

Huge! Electrostatic forces are strong.
Coulomb’s Law: Action at a Distance?

- One charged object exerts a **force** on another.
- Like charges repel, unlike charges attract.
- How can a force be exerted at a distance?
- Next chapter: **the electric field.**
The inverse square law

- True for both electricity and gravity! Why?
- Because space is three-dimensional.
- \( F \propto \frac{1}{r^2} \)
- If \( r \rightarrow 2r \) then \( F \rightarrow F/4 \)
- The force is inversely proportional to the square of the distance
The Coulomb Law Constants

Coulomb’s experiment gives

\[ F = k \frac{Q_1 Q_2}{R^2} \]

and determines the *electrostatic constant*

\[ k = 8.99 \times 10^9 \approx 9 \times 10^9 \quad \text{SI units} \]

This is often written as

\[ k = \frac{1}{4\pi \varepsilon_0} \]

with the *permittivity constant* having the value

\[ \varepsilon_0 = 8.85 \times 10^{-12} \quad \text{SI units} \]
Example 1
Two charges are separated by 3 meters. If each charge is 2 microcoulombs, what is the force by one charge on the other?

Solution

\[ Q = 2 \mu C = 2 \times 10^{-6} C \]

\[ F = k \frac{Q^2}{r^2} = \frac{9 \times 10^9 \times (2 \times 10^{-6})^2}{3^2} \]

\[ F = \frac{9 \times 4 \times 10^{-3}}{9} = 4 \times 10^{-3} N \]
Two charges are separated by 2 m and repel each other with a force of 20 N. If they are moved to a separation of 4 m, what will be the repulsive force?

1. 5 N
2. 10 N
3. 20 N
4. 40 N
5. 80 N
Example 2

What is the net force on the charge $q$ due to the charges $Q_1$ and $Q_2$ placed as shown?

$Q_1 = 4 \mu C$

$q = 1 nC$

$Q_2 = -3 \mu C$

$d = 3 mm$
Example 2 (cont’d)  What is the net force on \( q \)?

\[ d = 3 \text{ mm} \]

\[ q = 1 \text{ nC} \]

\[ Q_1 = 4 \mu \text{C} \]

\[ Q_2 = -3 \mu \text{C} \]

\[ F = F_1 + F_2 \]

\[ F = \sqrt{F_1^2 + F_2^2} = \sqrt{3^2 + 4^2} = 5 \text{ N} \]

\[ F_1 = k \frac{Q_1 q}{d^2} = 9 \times 10^9 \frac{(4 \times 10^{-6})(1 \times 10^{-9})}{(3 \times 10^{-3})^2} = 1 \times 10^{+15} \times 4 \times 10^{-15} \text{ N} = 4 \text{ N} \]

\[ F_2 = k \frac{Q_2 q}{d^2} = 9 \times 10^9 \frac{(3 \times 10^{-6})(1 \times 10^{-9})}{(3 \times 10^{-3})^2} = 1 \times 10^{+15} \times 3 \times 10^{-15} \text{ N} = 3 \text{ N} \]

\[ \tan \theta = \frac{3}{4} \]

\[ \theta = 37^\circ \]
Example 2 (cont’d)

What is the net force on $q$?

OR:

$F_x = +4 \, N$

$F_y = -3 \, N$