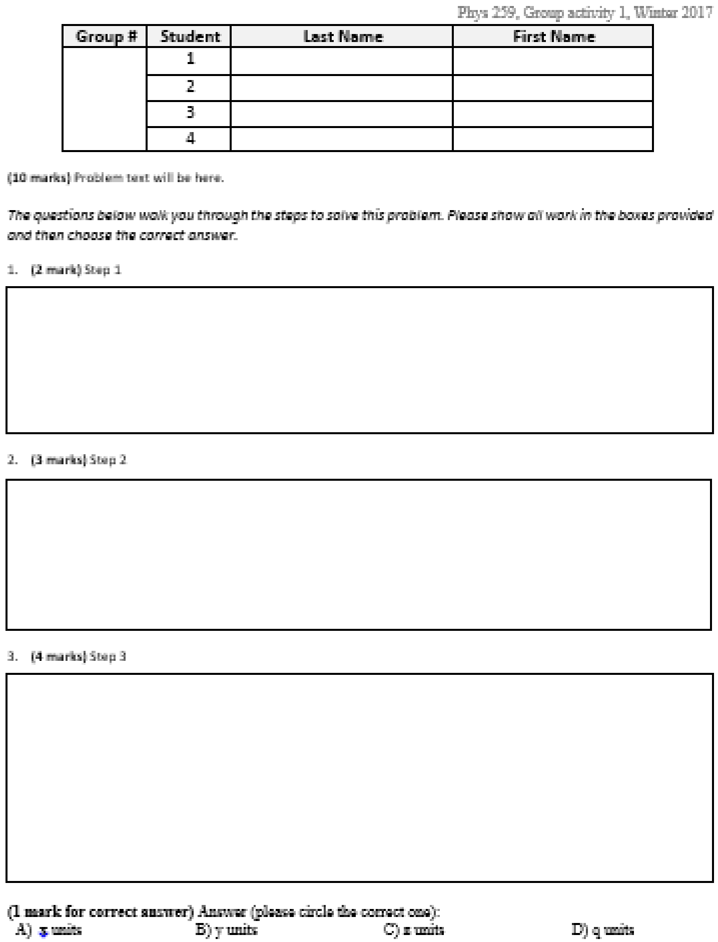
Announcements

Friday class activities

- Purpose: to help you develop problem solving skills for midterm and final exam
- Activity: problem with steps you need to take in order to solve it (showing your work); majority of the marks
- Final answer: MCQ (1 mark)
- Exams: no help with steps – MCQ only



Phys 259, Group activity 1, Winter 2017

Group #	Student	Last Name	First Name
	1		
	2		
	3		
	4		

(10 marks) Problem text will be here.

The questions below walk you through the steps to solve this problem. Please show all work in the boxes provided and then choose the correct answer.

1. **(2 mark)** Step 1
2. **(3 marks)** Step 2
3. **(4 marks)** Step 3

(1 mark for correct answer) Answer (please circle the correct one):
A) x units B) y units C) z units D) q units

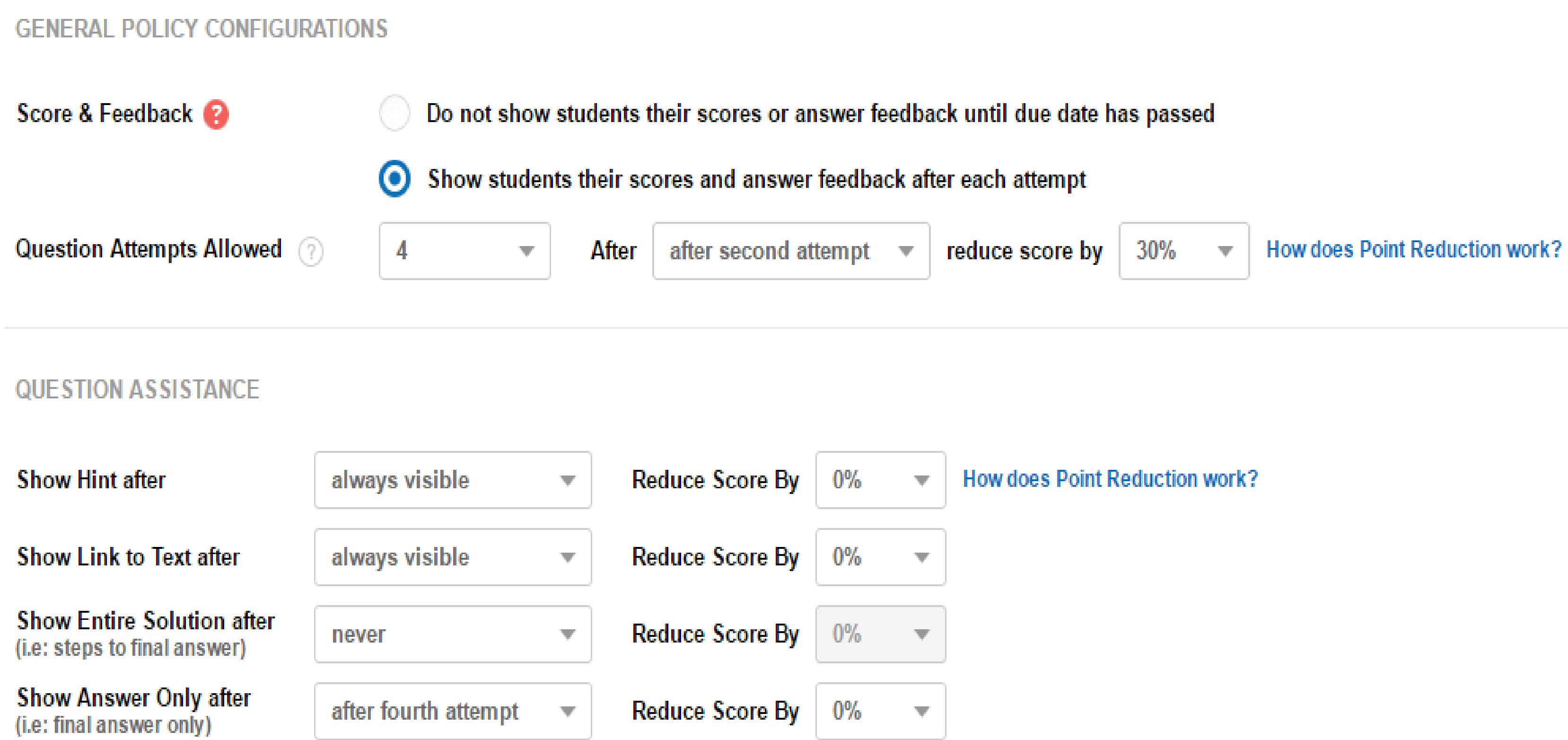
- Ask questions: lecture TAs and instructor

In-class activities

- Groups of 4 (assignment on Friday Jan 13, please sit next to your preferred peers, if known)
- Each group will be given a number to self-enroll on D2L on Friday
- Groups stay the same for the entire term
- Activity (30 min); submission via group Dropbox
- File should include group number and names of peers present that day
- Submit PDF file (please install the app on your phone/ tablet: https://www.camscanner.com/)
- Submission by the end class (+ 10 min grace period), late submission = no grade

WileyPlus settings

- 4 attempts, 30% deduction after second attempt
- Settings are posted on D2L (folder: WileyPlus)



Last time

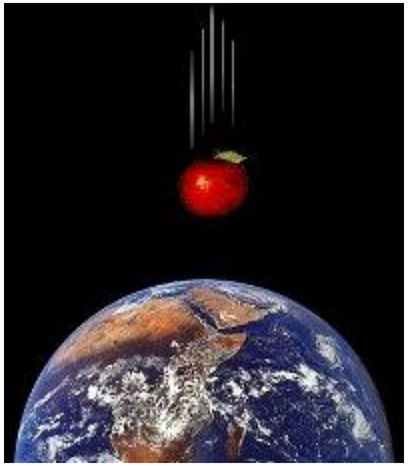
- Forces in nature
- Gravitational force
- Electromagnetic force

This time

- Comparison of the gravitational and electromagnetic force between two electrons
- Strong and weak nuclear forces
- Structure of matter
- Fundamental particles

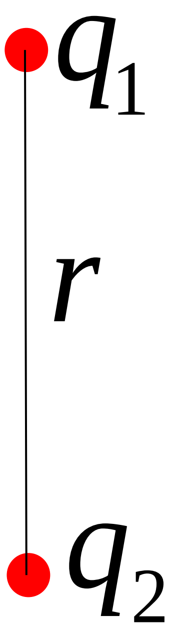
Magnitude of Gravitational force

$$F_{m_1 \text{ on } m_2} = F_{m_2 \text{ on } m_1} = G\frac{m_1 m_2}{r^2}$$



Magnitude of Electromagnetic force

$$F_{q_1 \text{ on } q_2} = F_{q_2 \text{ on } q_1} = k_e\frac{q_1 q_2}{r^2}$$

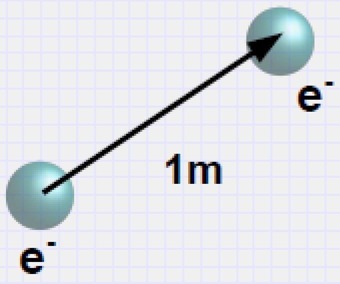


Comparing gravitational force and electromagnetic force between two electrons at 1 m apart.

Gravitational force

Consider two electrons separated by 1 metre.

Compare the magnitude of the forces on each charge due to electricity and gravity.

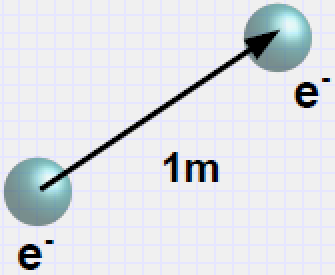


The gravitational force (attraction) is *very* small

$$
\begin{aligned}
F_g &= G\frac{m_1 m_2}{r^2} \\
&= 6.67\times10^{-11}\frac{N\,m^2}{kg^2}\times\frac{(9.11\times10^{-31}\,kg)^2}{(1.0\,m)^2} \\
&= 5.54\times10^{-71}\ \text{Newtons}
\end{aligned}
$$

Electromagnetic force

The electric force calculated from Coulomb's law



$$F_e = k\,\frac{q_1 q_2}{r^2}$$

$$= 8.99\times10^{9}\,\frac{N\,m^2}{C^2}\times\frac{(-1.60\times10^{-19}\,C)^2}{(1.0\,m)^2}$$

$$= 2.30\times10^{-28}\ \text{Newtons}$$

is also very small in absolute terms, but ...

Comparing the forces

...but relative to the gravitational force it is immense

$$\frac{F_e}{F_g} = \frac{2.30\times10^{-28}\ N}{5.54\times10^{-71}\ N} = 4.15\times10^{42}$$

No units

For this particular case the gravitational force is utterly negligible compared to the electric force.

On large scales gravity tends to become more important because masses always add, while charges tend to cancel each other out.

The acceleration of each electron can be found using Newton's Law

$$F = m a$$

$$a = \frac{F}{m} = \frac{2.30\times10^{-28}\,kg\,m/s^2}{9.11\times10^{-31}\,kg} = 250\,m/s^2$$

It is *very* difficult to simply gather large numbers of charges with the same sign in a small region. Similarly, separating charges with opposite signs requires a significant amount of work.

25 time the gravitational acceleration due to the entire Earth.

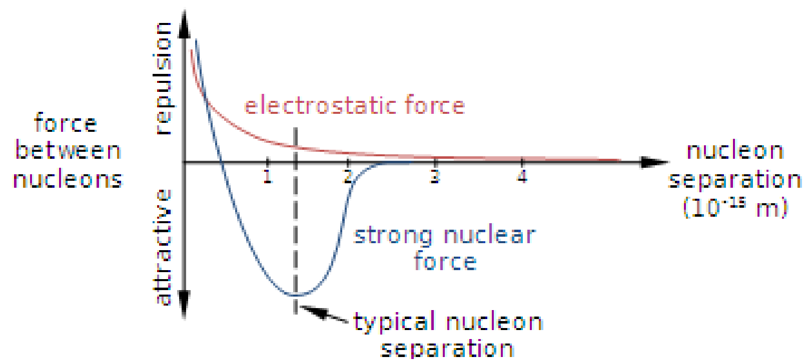
Strong nuclear force

Weak or strong? Strong.

Long or short range? Very short-range (~ 10^{-15} m)

Attractive or repulsive? Both.

Attractive over the size of the nucleus and very weak for larger distances. Repulsive over distances shorter than the size of the nucleus.



Responsible for holding the protons and neutrons as well as atomic nuclei together.

Weak nuclear force

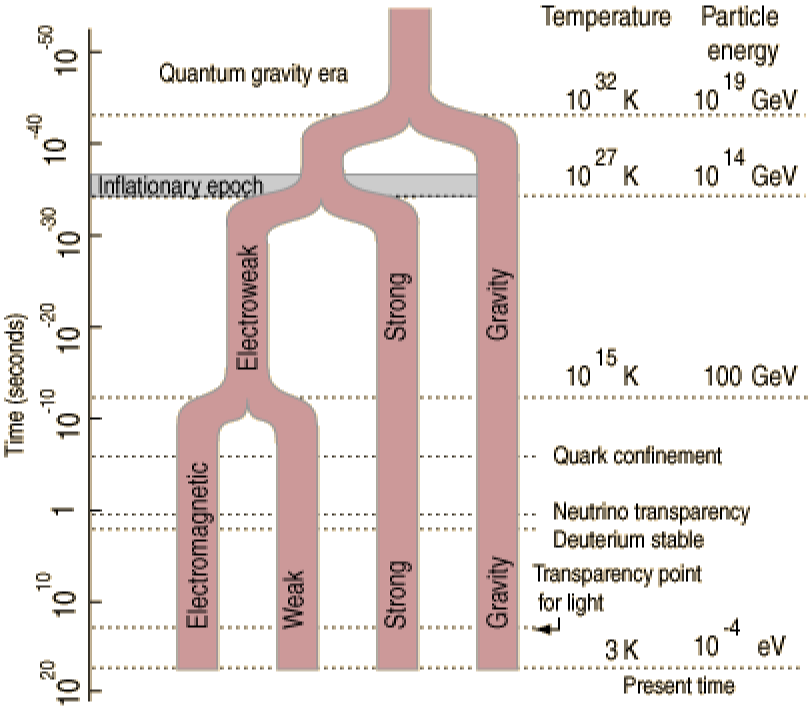
Responsible for radioactive decay and fusion reactions in the sun. Very short-range ($\sim 10^{-17}$ m).

It explains, for example, why ^{12}C is stable and ^{11}C is not.

Unification of forces?

Modeling of the "Big Bang" expansion of the universe at earlier and earlier times has led to the use of the "Planck time" of 10^{-43} seconds as a proposed interval during which all the fundamental forces were unified into a single force.

This figure is an attempt to illustrate the "spontaneous symmetry breaking" which is presumed to have separated the original force into the four forces which we see operating in the present, low temperature universe. Proposed energies and temperatures associated with each of the symmetry breaks are shown along with a modeling of the time elapsed in the big bang model.



CERN's highest energy 10^4 GeV

What is electromagnetism?

- Electric forces between objects carrying an electric charge.
- Chemical bonds between atoms:
  - Ionic bond is when one atom gives another atom an electron, creating two oppositely charged ions that stick together.
  - Covalent bond is when two atoms share electrons.
- Van der Waals bonds responsible for formation of liquids and solids from the gas phase.
- Currents flowing through wires that power electronic devices.
- Magnetic forces between objects carrying electric currents.
- The force responsible for keeping me from falling through the floor.
- Much, much more.

Key concepts

- Matter is composed of charged particles and charge is conserved.
- Charge can produce electric forces (Coulomb’s Law) or electric fields (Gauss’s Law)between atoms:
- Electric forces or fields can move charge to produce currents (Ohm’s Law)
- Currents can produce magnetic fields (Biot-Savart Law, Ampere’s Law).
- Changes in magnetic fields can produce electric fields (Faraday’s Law).

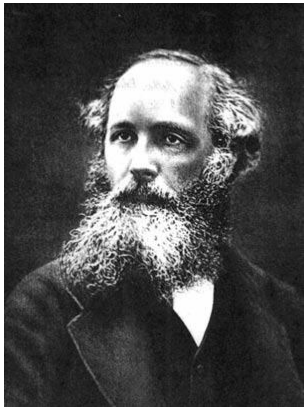
The wonderful Maxwell's Equations

$$\oint \vec{E} \bullet d\vec{A} = \frac{Q_{enclosed}}{\varepsilon_0}$$ Gauss's Law for electricity

$$\oint \vec{B} \bullet d\vec{A} = 0$$ Gauss's Law for magnetism

$$\oint \vec{B} \bullet d\vec{l} = \mu_0 \left(i_c + \varepsilon_0 \frac{d\Phi_E}{dt} \right)$$ Ampere's Law

$$\oint \vec{E} \bullet d\vec{l} = -\frac{d\Phi_B}{dt}$$ Faraday's Law



James Clerk Maxwell
(1831 – 1879)

There are also the differential forms of Maxwell's equations.

Among other things, they explain the behaviour of light.