BEFORE CLASS:
dig into your memory for what you know about the gravitational force

RECITATIONS START THIS Thursday!

FIRST HOMEWORK ASSIGNMENT IS DUE 11:59PM Tuesday Sept 8

class web site
http://www.physics.rutgers.edu/ugrad/227H

Physics 227H: Honors Analytical Physics II

electricity and magnetism

Problem solving techniques and strategies
Both numerical and symbolic
More conceptual, more mathematical than 227

Electricity and magnetism

Textbook:
Halliday, Resnick and Walker, 10th edition

class web site
http://www.physics.rutgers.edu/ugrad/227H

the instructors

Prof. Karin Rabe (lectures): theoretical materials physics
PhD in physics from MIT 1987
AT&T Bell Labs 1987-1989, on the faculty at Yale 1989-2000
on Rutgers faculty since 2000
Board of Governors Professor and member of the National Academy of Sciences, 2013

Siddhartha Saha
recitations; PhD student in biophysics, focusing on machine learning

The lectures

55 minutes, 2x per week + a LOT of material
This can only work with our full attention!

CLASS GUIDELINES

- Please keep your video on
- Name yourself with the first name you want to be called (you should correct me if I don't pronounce correctly) and your last name
- Stay muted during the lecture portions
- Answer all the poll questions to the best of your ability – they are not graded but they let me know if we need to discuss more about a particular concept

want to get the maximal benefit for effort put in

The recitations

1 hour 20 minutes, 1x per week
Taught by PhD student Siddhartha Saha

- Math topics
- Solving example problems as a bridge between the lectures and the homework

Pre-recitation problems

These are the “easy” warm-up problems that review the physics you have learned before and help you transition to the problems assigned in the homework

Problems will be posted on the class website.

You should do the problems BEFORE recitation and if you have any difficulties, visit the background reading link or ask one of the instructors

Bring the problems and your solutions to recitation for discussion/presentation

Homework

WebAssign
Due Tuesdays 11:59 PM

WebAssign class key: rutgers 9188 7020

Office hours

Professor Rabe
Sundays 6:00-7:30 PM
Mondays 11:00-12:00
Tuesdays 11:00-12:00
on Zoom

TA office hours to be announced

Coursework and Grades

Exam 1: 15%, Exam 2: 20%, Final: 30%, HW: 20%, Quiz 15%

Exams 1 and 2 will be in class

First recitation this week

1st HW due: Tuesday September 8 at 11:59PM

Physics department gradebook – link on class website

N2: $\vec{F} = m\vec{a}$

If acceleration of an object is nonzero, there must be a net force on the object

Force and acceleration are VECTORS direction and magnitude

UNITS – SI
Acceleration m/s2
Force N
Mass kg

N2: $\vec{F} = m\vec{a}$

UNITS – SI

Acceleration m/s^2

Force N

Mass kg

1 N = (1 kg) (1 m/s^2)

Types of forces that you learned about in Analytical Physics I

Contact forces:
“applied” force = push
normal force (at a surface)
String tension: pull
Static and kinetic friction, drag force

Force at a distance:
gravity

A new force

Bill Nye will demonstrate for us:
https://www.youtube.com/watch?v=oU8Fe6846d4

A new force

Gravity	new force
Acts at a distance	Acts at a distance
Attractive	Attractive AND repulsive
very small	easy to make large
Proportional to mass	proportional to "electric charge"

Electricity and magnetism

Focus on “fields” as fundamental entities
Electric field **E**(**r**)
Magnetic field **B**(**r**)

First example of a “classical field theory”
First example of a “unified field theory”

Electromagnetism

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0} \qquad \nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} \qquad \nabla \times \mathbf{B} = \mu_0 \mathbf{j} + \frac{1}{c^2}\frac{\partial \mathbf{E}}{\partial t}.$$

Maxwell’s equations: fields, charge, current

$$\mathbf{F} = q(\mathbf{E} + v \times \mathbf{B}).$$

Electromagnetism

$$\oint \vec{E} \cdot d\vec{A} = q_{\text{enc}}/\varepsilon_0 \qquad \oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt}$$

$$\oint \vec{B} \cdot d\vec{A} = 0 \qquad \oint \vec{B} \cdot d\vec{s} = \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt} + \mu_0 i_{\text{enc}}$$

Maxwell's equations: fields, charge, current

$$\mathbf{F} = q(\mathbf{E} + \boldsymbol{v} \times \mathbf{B}).$$

Electrostatics: HRW Chapters 21-25

$$\oint \vec{E} \cdot d\vec{A} = q_{\text{enc}}/\varepsilon_0 \qquad \oint \vec{E} \cdot d\vec{s} = 0$$

Maxwell's equations: electric field & charge

F = q **E**

A new force

Gravity	new force
Acts at a distance	Acts at a distance
Attractive	Attractive AND repulsive
very small	easy to make large
Proportional to mass	proportional to "electric charge"

Charge, like mass, is a scalar property of objects/particles.
Mass is positive
Charge can be positive or negative

Masses attract	Like charges repel
	opposite charges attract

Force laws for two point particles

Law of gravity (HRW 13-2)
Force on particle 2 due to particle 1 is directly towards particle 1
Magnitude depends on inverse square of separation
Unit of mass is kilograms (kg)
$G = 6.67408 \times 10^{-11}$ N m^2/kg^2

$$F = G\frac{m_1 m_2}{r^2}$$

Law of electric force (Coulomb's law) (HRW 21-4)
Force on particle 2 due to particle 1 is along line connecting them
Magnitude depends on inverse square of separation
Towards particle 1 if $q_1q_2<0$, away if $q_1q_2>0$

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

Unit of charge is Coulombs (C)
$k = 8.99 \times 10^9$ N m^2/C^2
Force on particle 1 due to particle 2 satisfies Newton's 3rd law

Compute the gravitational and electric forces for two protons

$$F = G\frac{m_1 m_2}{r^2}$$

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

For r = 1 nm

Ratio: $G\, m^2 / (k\, e^2)$

Compute the gravitational and electric forces for two protons *(attn to units and sig figs)*

$$\frac{kq^2}{r^2} = 8.99 \times 10^9 \frac{Nm^2}{C^2}(1.60 \times 10^{-19} C)^2 / (1.00 \times 10^{-9} m)^2$$

$$\frac{Gm^2}{r^2} = 6.67 \times 10^{-11} \frac{Nm^2}{kg^2}(1.67 \times 10^{-27} kg)^2 / (1.00 \times 10^{-9} m)^2$$

2.30×10^{-10} N vs 1.86×10^{-46} N

Ratio is independent of r: 8.08×10^{-37}

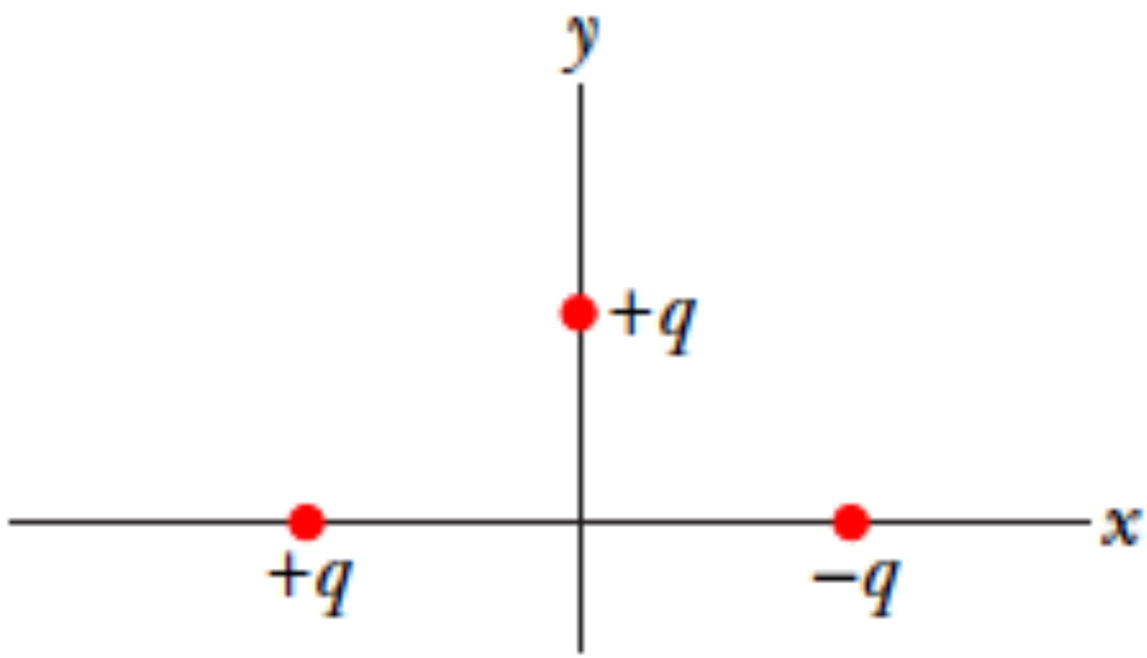
Force law for more than two point particles

SUPERPOSITION: forces on particle add like vectors (HRW 21-4)
(also true for gravitational force: HRW 13-3)

$$\vec{F}_1 = \vec{F}_{12} + \vec{F}_{13}$$

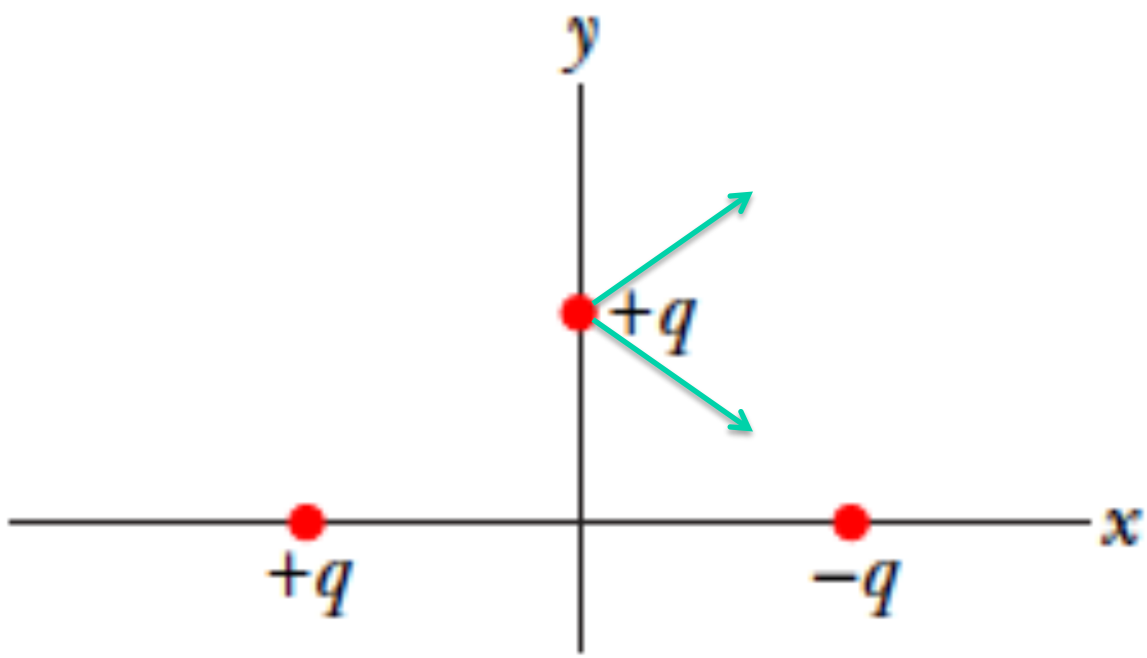
Example:

What is the direction of the net electric force on the middle particle, if the particles on the x axis are equidistant from the origin?



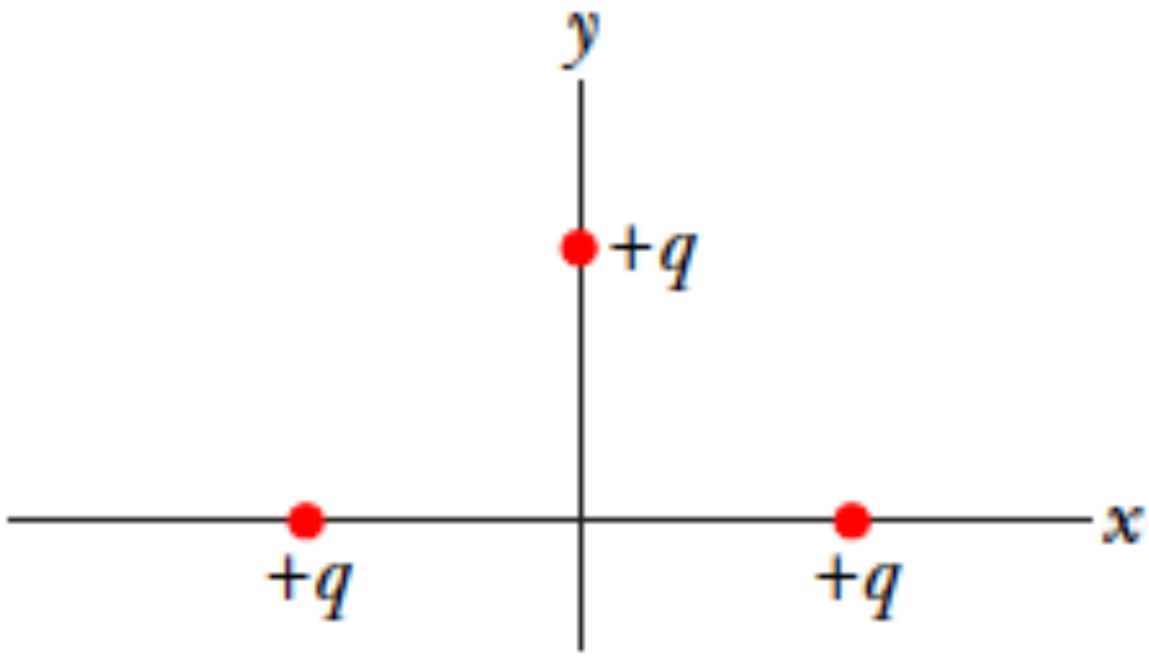
Example:

What is the direction of the net electric force on the middle particle, if the particles on the x axis are equidistant from the origin?



Example:

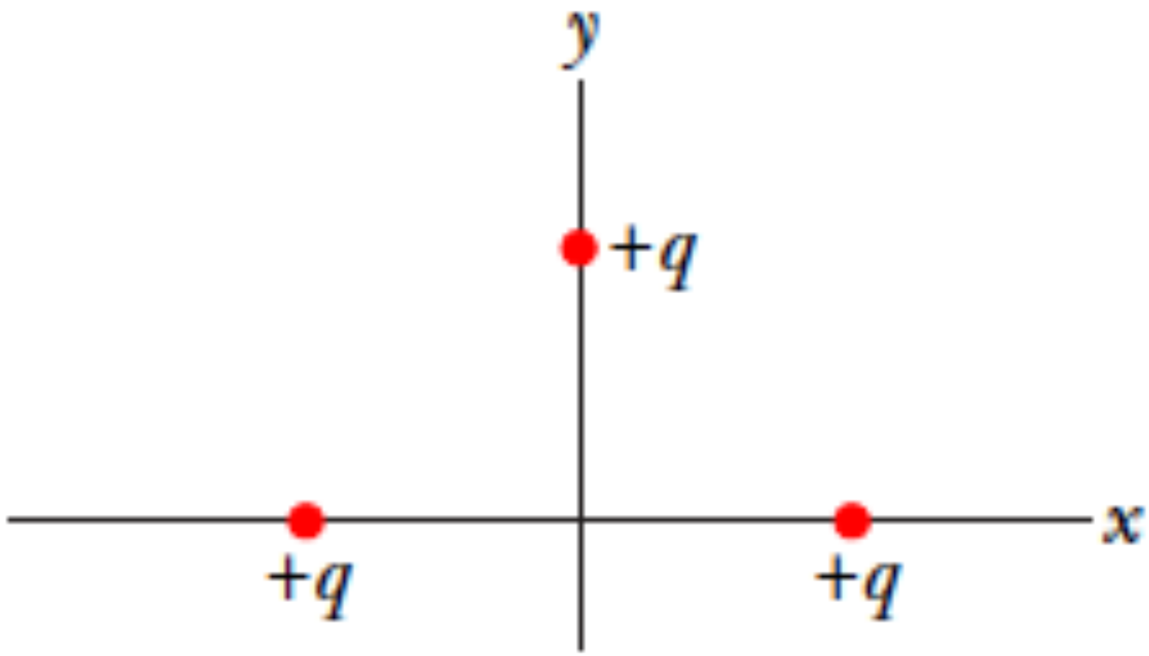
What is the direction of the net force on the middle particle, if the particles on the x axis are equidistant from the origin?



(1)

Example:

What is the direction of the net force on the middle particle, if the particles on the x axis are equidistant from the origin?



(1)

SYMMETRY

Four particles with identical charges q are arranged as shown below. In which of the three arrangements is the magnitude of the net electric force on the central charge LARGEST?