Welcome to Physics 122

Professor Gray Rybka

Content: Electricity & Magnetism

Format: *Active Learning* (Learn from Participation)

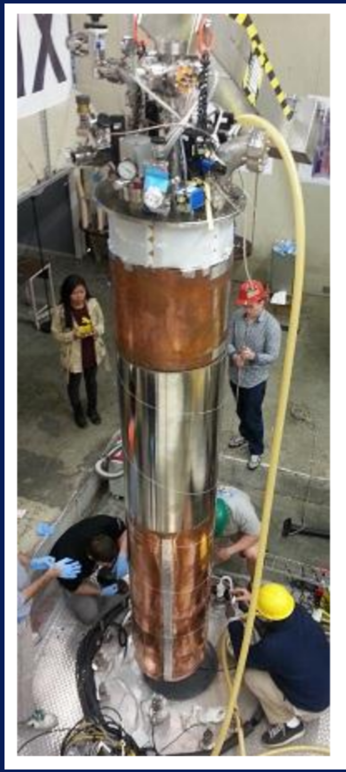
- » Course Reading
- » PreLectures & Checkpoints (FlipitPhysics)
- » Lectures (presentations, demonstrations, & Clickers)
- » Homework (problem solving)
- » Tutorials (concepts in depth)
- » Labs (hands-on interactions with the phenomena)

Here → (PreLectures & Checkpoints, Lectures, Homework)

Lecture thought:

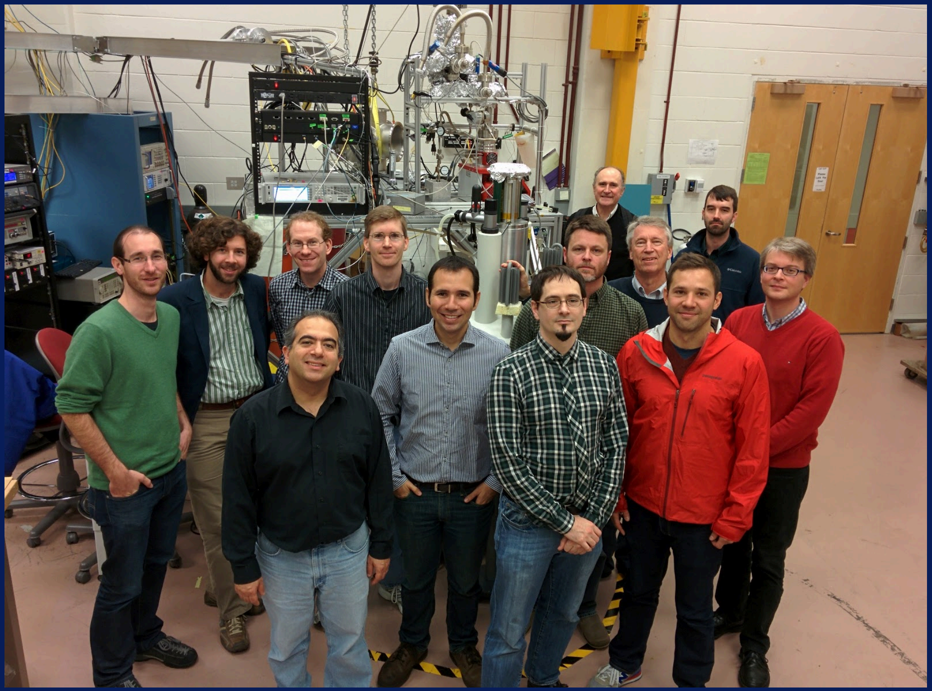
Introduce yourself and your background - Why are you an expert in this field?

My experiments …



ADMX – searching for a proposed dark matter particle called the axion through its conversion into electromagnetic radiation in the presence of a strong magnetic field

Project 8 – precision measurement of electron energies via frequency measurement of the electromagnetic radiation they emit in a magnetic field (This turns out to be an important step in measuring the neutrino mass)



Web and Grading Policy

- **Course webpage: http://faculty.washington.edu/grybka/phys122/index.shtml**
- **Links to other aspects of course (SmartPhysics / FlipitPhysics) , WebAssign, …)**
  - **PDFs of Lecture slides will be linked there after each lecture**
  - **Policy statements**
  - **Exam prep / follow-up items**

- Grading Policy (just like 121). Grade is achievement based. Earn the points, get the grade. Many points are earned by just doing the work (HW, Clickers, SmartPhysics, Lab work …)

1000 point system

Midterms (best 2 of 3)	37% 370
Final Exam	28% 280
Lab Section	11% 110
Tutorial Section	8% 80
Lecture HW	8% 80
SmartPhysics	4% 40
Clickers in class	4% 40

A couple of quick Clicker questions

(there are no right answers to these)

Clicker Registration survey will start in a few days
Your answers are being recorded already

Flipit Physics

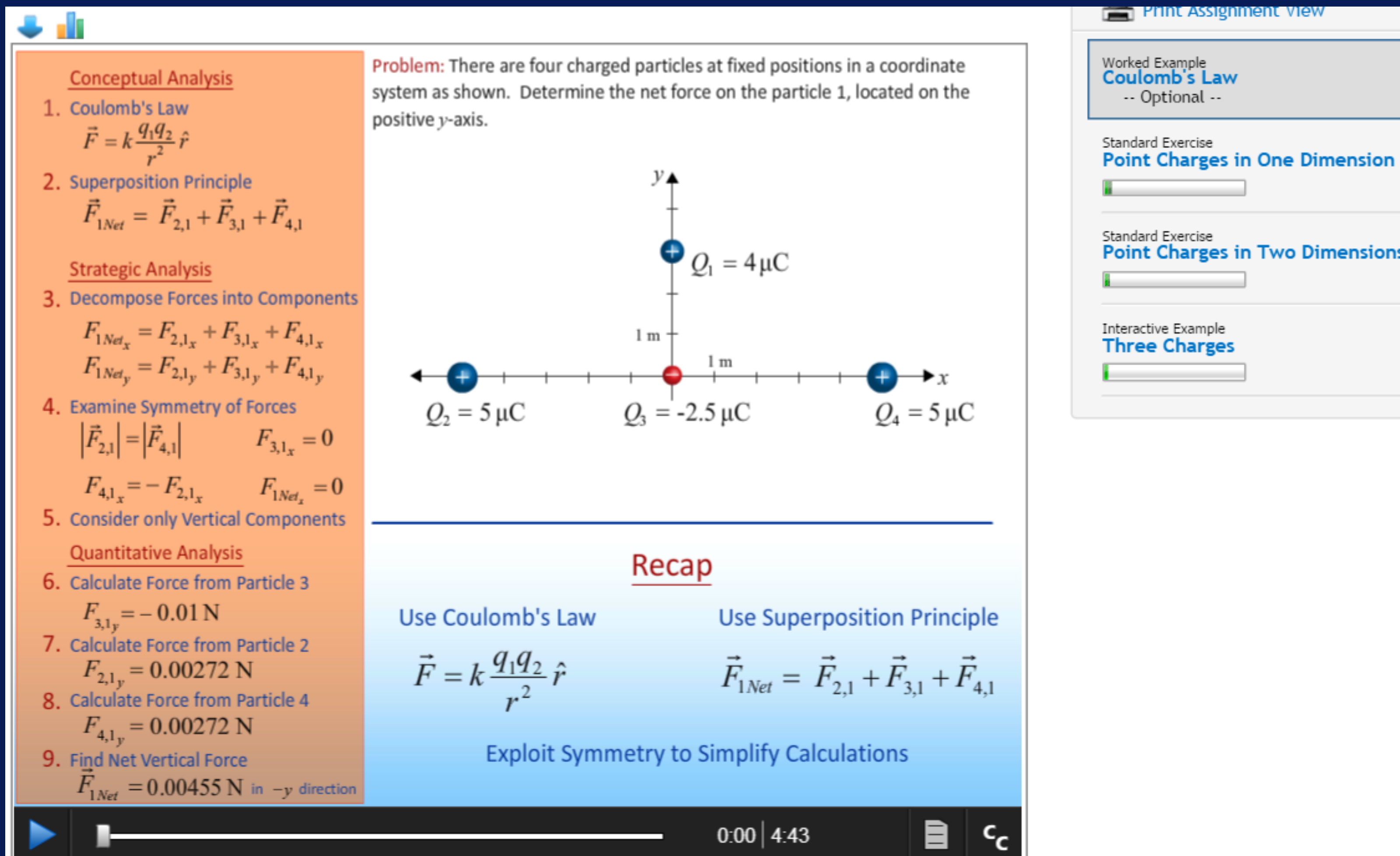
- Registration email went out this morning

- Some of you may have had problems with registration

- I moved today’s deadline to Wednesday morning at 10 am

- Remember: Flipitphysics homework is entirely optional!!
- (Prelecture and checkpoints are mandatory)

Some SP Homework includes a worked example with narration



A couple more things…

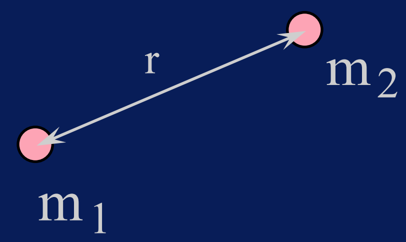
- Study Center will be open soon
- My regular office hours (I will be available this week)
  - Friday 11:30-12:30 (after class) C501; Physics questions / problems / group

- WebAssign HW is posted and setup. Homework due Wednesdays at 9 pm. 1st one due *next* week.

- If you did NOT get an email from me, check your UW email account.
- Final exams
- 122 A Final Monday: June 6, 2016

The World According to Physics 121

- **Objects**
  - Specified by geometry and mass
- **Forces**
  - Gravity: $F = G\frac{m_1 m_2}{r^2}$



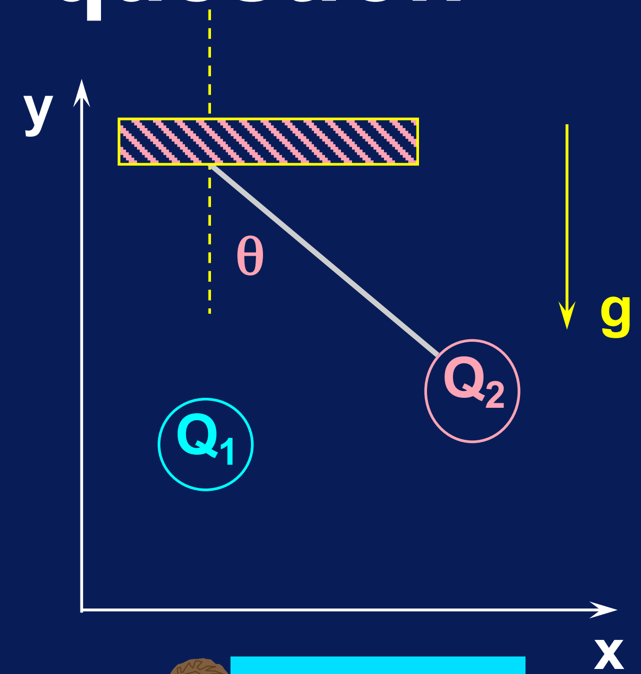
  - Others: Tension, Normal, Friction
- **Space and Time**
  - Euclidean with Galilean Invariance
    - “ordinary” 3D space; “slow” velocities

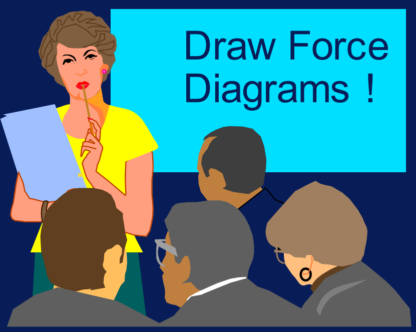
What Do You Expect?

Given framework established by Newton (1687), the task at hand is to find the form for other forces in the world.

Let's start with a Clicker question

- A charged ball Q_1 is placed next to another charged ball Q_2 which is connected to a string. Q_2 comes to equilibrium at angle θ as shown.
  - From this observation, we can already learn something about the nature of the electrical force F_E exerted by Q_1 on Q_2
  - Example, what is the sign of each component of the force; ie, F_{Ex} and F_{Ey} ?



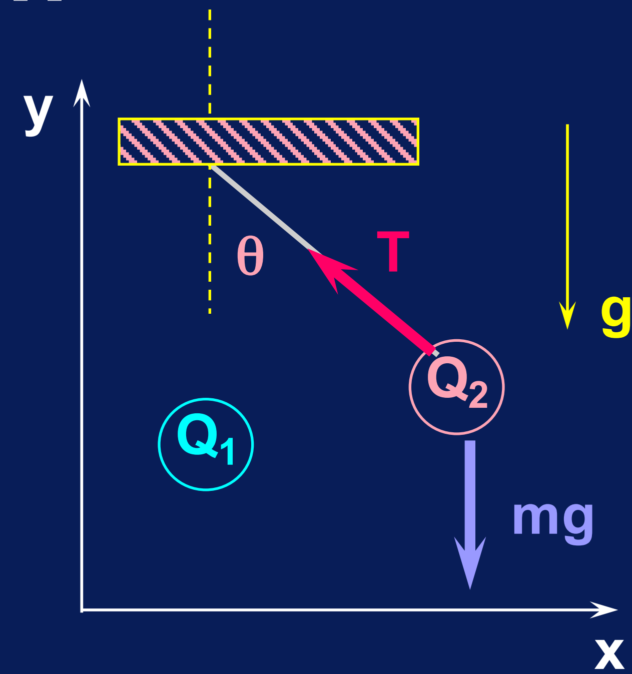


1a: A) $F_{Ex} < 0$
B) $F_{Ex} > 0$
C) Cannot determine sign of F_{Ex} from this information

1b: A) $F_{Ey} < 0$
B) $F_{Ey} > 0$
C) Cannot determine sign of F_{Ey} from this information

Clicker - solution

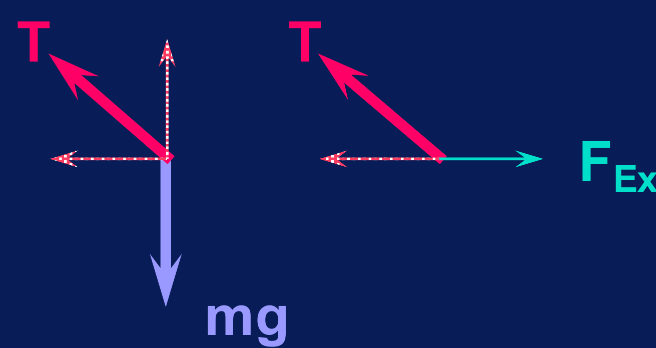
A charged ball Q_1 is placed next to another charged ball Q_2 which is connected to a string. Q_2 comes to equilibrium at angle θ as shown.



1a: A) $F_{Ex} < 0$
B) $F_{Ex} > 0$
C) Cannot determine sign

Two forces act on Q_2

- its weight (mg)
- the tension (T) in the string



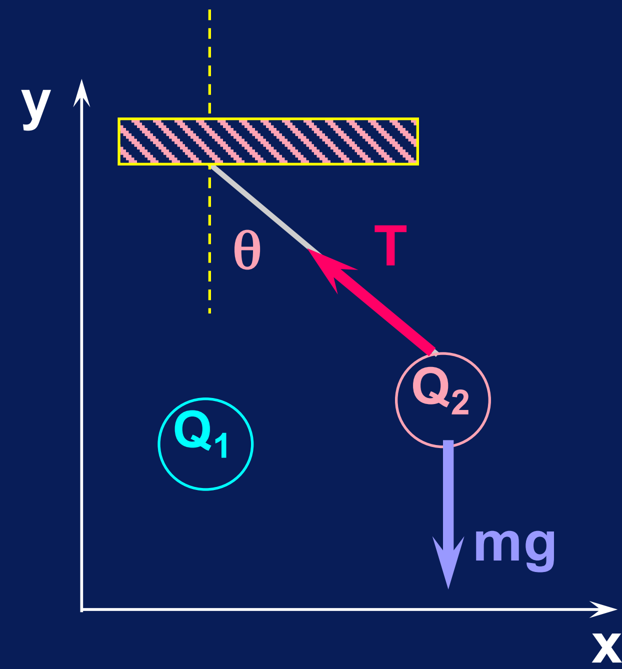
T has an x-component; mg does not.

Equilibrium: the net force on Q_2 must be zero

The electrical force (F_E) must at least have an x-component to cancel the x-component of the tension (T).

Therefore, **B) $F_{Ex} > 0$**

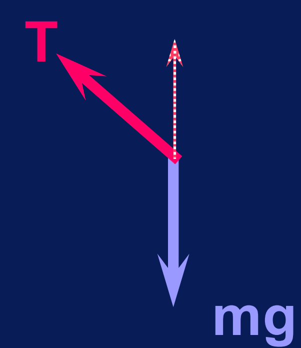
Clicker - solution



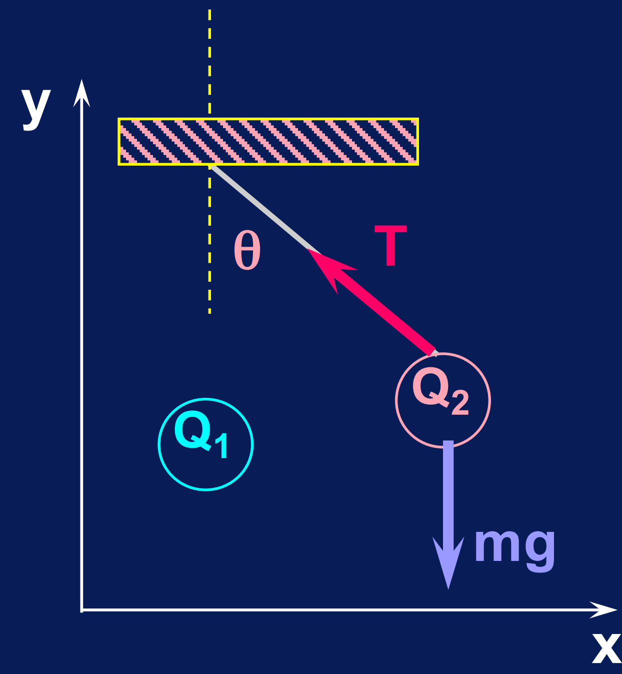
Now consider F_{Ey}

1b: A) $F_{Ey} < 0$
B) $F_{Ey} > 0$
C) Cannot determine sign

T and mg have y-components of opposite sign, so at first glance it may look like we can say nothing about F_{Ey}.



Clicker - solution



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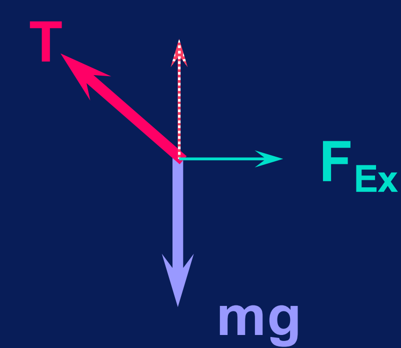

Remember that the Electrical Force has a positive x component...

Clicker - solution

Now consider F_{Ey}

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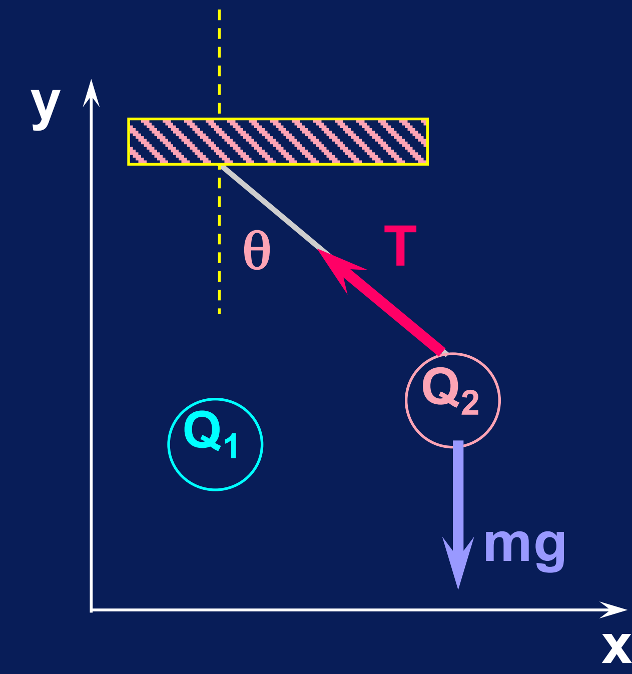
C) Cannot determine sign



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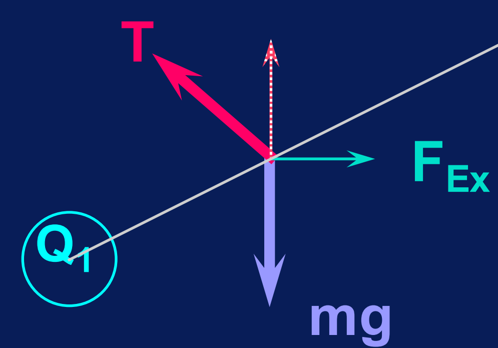


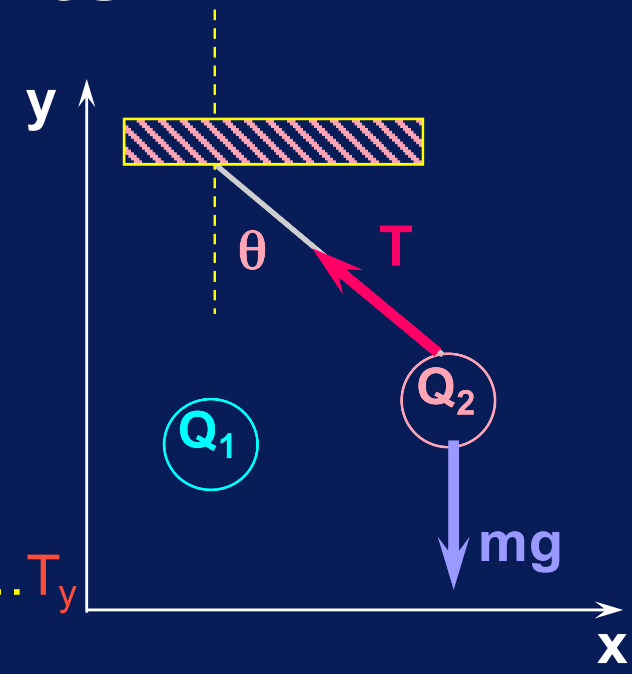
Remember the Electrical Force has a positive x component…

Assume, a *CENTRAL* force. It acts along the white line connecting the two charges

B) $F_{Ey} > 0$

Follow-up thoughts

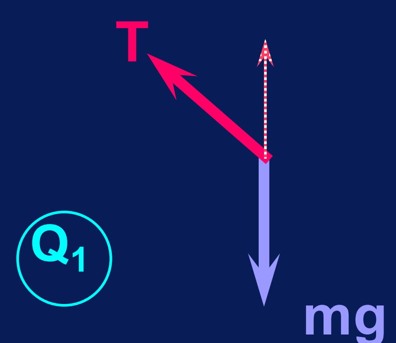
Is this a reasonable assumption?



What if there was NO F_{Ey} ???

Then, the only force Q_2 feels from Q_1 is to the right…T_y and mg balance

You could argue: C) Cannot determine the sign



Assumes, some preferred direction in space.

Not likely

But stay tuned. Non-Central Forces will invade our study soon !

What Do You Expect?

Given framework established by Newton (1687), the task at hand is to find the form for other forces in the world.

What happened?

Electric & Magnetic Phenomena were known by the Greeks, but the theory did not gain its "final form" until Maxwell(1873).

Why?

The complexity of the problem and by the need to include a new fundamental entity (Fields) into the physical world picture.

Lecture thought:
Unlike mechanics, I find it more difficult to visualize the interactions between charges which makes visualization and checking answers much more difficult -Devin-

Fields: A Preview of Physics 122

- Some Demos …

- Energy
  - Mechanical (bowling ball pendulum)
  - Electrical (capacitors)

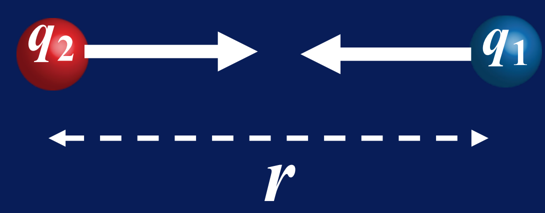
- Fundamental Connections between Electric Fields & Magnetic Fields
  - Faraday's Law (Motors and Generators)
  - Electromagnetic Waves (examples: microwaves, polarization)

Where Does Our Study Start?

- The Phenomena
  - Fur on rubber $\Rightarrow$ rubber $\rightarrow$ negative
  - Silk on glass $\Rightarrow$ glass $\rightarrow$ positive
- The Concept
  - Electric Charge
    - Attribute of body
    - Unlike charges attract
    - Like charges repel

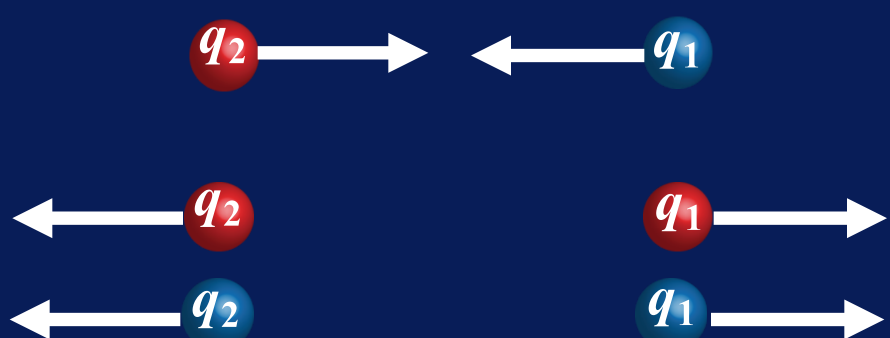
Coulomb's Law:

The force on a charge due to another charge is proportional to the product of the charges and inversely proportional to the separation squared.



$$F \propto \frac{q_1 q_2}{r^2}$$

The force is always parallel to a line connecting the charges, but the direction depends on the signs of the charges:



Opposite signs attract

Like signs repel

Coulomb's Law

Our notation:

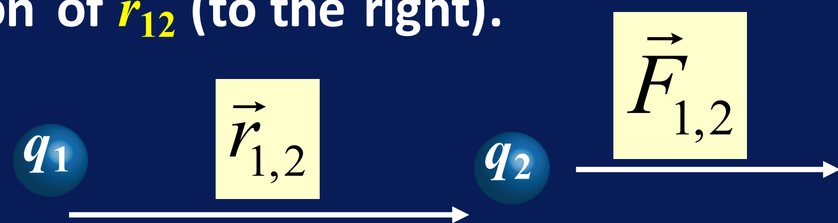
$\vec{F}_{1,2}$ **is the force by 1 *on* 2 (think "*by-on* ")**

$\hat{r}_{12}$ **is the unit vector that points *from* 1 *to* 2.**

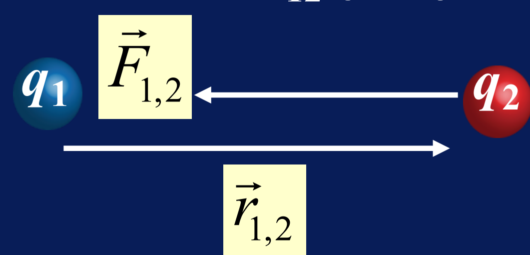
$$\vec{F}_{1,2} = \frac{kq_1 q_2}{r_{1,2}^2}\hat{r}_{1,2}$$

Examples:

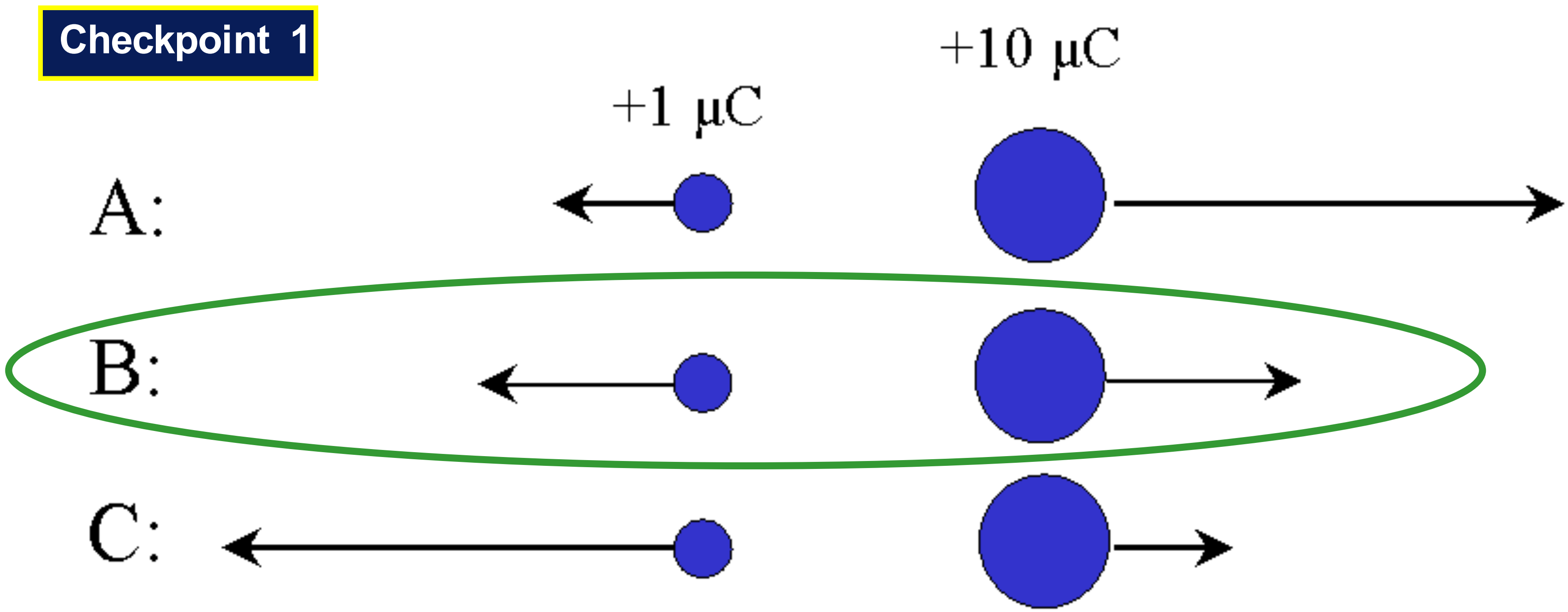
If the charges have the same sign, the force by charge 1 on charge 2 would be in the direction of r_{12} (to the right).

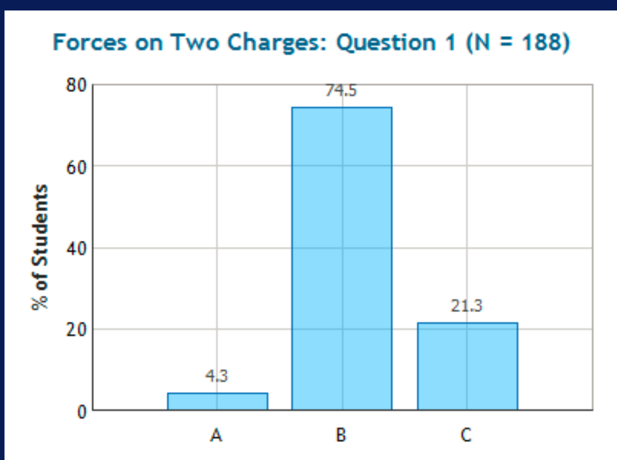


If the charges have opposite sign, the force by charge 1 on charge 2 would be opposite the direction of r_{12} (left).



1) Two charges $q = +1\ \mu C$ and $Q = +10\ \mu C$ are placed near each other as shown in the figure. Which of the following diagrams depicts the forces acting on the charges:





A) …

B) The arrows point in opposite directions because both charges are positive. The repulsion will have the same length because of Newton's 3rd Law. We state that the two charges have an equal force on each other, which is the cause for their equal vector length. - Ariel -

C) …

Good Job. You remembered … Newton's 3rd

Clicker setup …

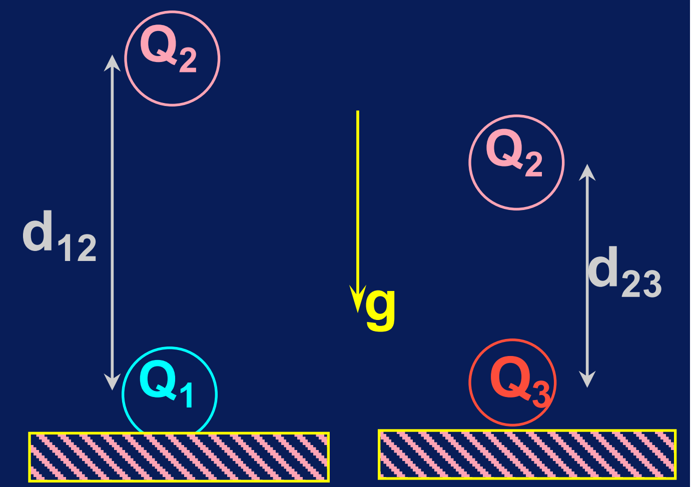
A charged ball Q_1 is fixed to a horizontal surface.

Another charged ball Q_2 is brought near

It achieves equilibrium at a distance d_{12} above Q_1.

Q_1 is replaced by Q_3, and

Q_2 achieves equilibrium at d_{23} ($< d_{12}$)



Assume the electrical force is a *Central Force*, which …

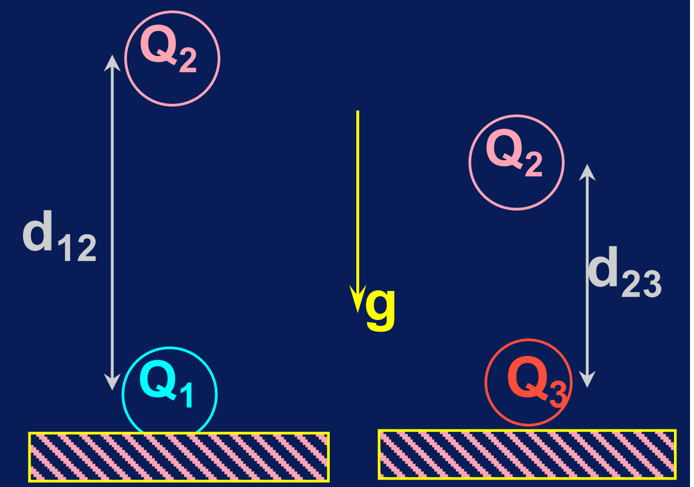
increases if the magnitude of one of the charges increases, and

increases if the distance between the charges is decreased.

2 (easy) Questions

A charged ball Q_1 is fixed to a horizontal surface.
Another charged ball Q_2 is brought near
It achieves equilibrium at a distance d_{12} above Q_1.

Q_1 is replaced by Q_3, and
Q_2 achieves equilibrium at d_{23} ($< d_{12}$)



1st:
A) The charge of Q_3 has the same sign of the charge of Q_1
B) The charge of Q_3 has the opposite sign as the charge of Q_1
C) Cannot determine the relative signs of the charges of Q_3 & Q_1

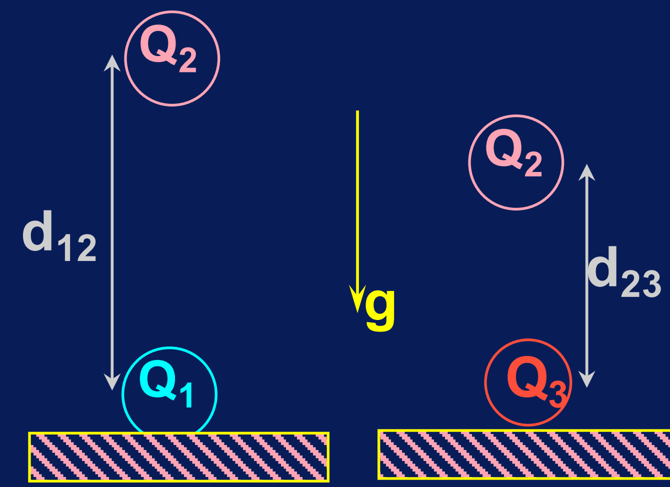
2nd:
A) The magnitude of charge Q_3 < the magnitude of charge Q_1
B) The magnitude of charge Q_3 > the magnitude of charge Q_1
C) Cannot determine relative magnitudes of charges of Q_3 & Q_1

Solution

A charged ball Q_1 is fixed to a horizontal surface.

Another charged ball Q_2 is brought near

It achieves equilibrium at a distance d_{12} above Q_1.



Q_1 is replaced by Q_3, and

Q_2 achieves equilibrium at d_{23} ($< d_{12}$)

- Force increases if the magnitude of one of the charges increases
- Force increases if the distance between the charges is decreased

1st: A) The charge of Q_3 has the same sign of the charge of Q_1

B) The charge of Q_3 has the opposite sign as the charge of Q_1

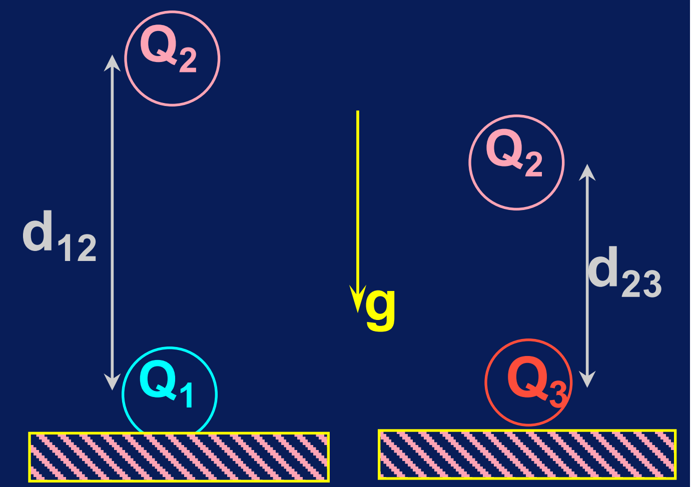
C) Cannot determine the relative signs of the charges of Q_3 & Q_1

- Equilibrium → the total force on Q_2 must be zero.
- Only known force acting on Q_2 is its weight.
- The electrical force on Q_2 must be directed upward to cancel its weight.
- Therefore, the sign of Q_3 must be the SAME as the sign of Q_1

Solution

A charged ball Q_1 is fixed to a horizontal surface.
Another charged ball Q_2 is brought near
It achieves equilibrium at a distance d_{12} above Q_1.

Q_1 is replaced by Q_3, and
Q_2 achieves equilibrium at d_{23} ($< d_{12}$)



- Force increases if the magnitude of one of the charges increases
- Force increases if the distance between the charges is decreased

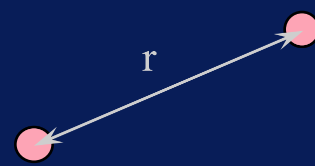
2nd: A) The magnitude of charge Q_3 < the magnitude of charge Q_1
B) The magnitude of charge Q_3 > the magnitude of charge Q_1
C) Cannot determine relative magnitudes of charges of Q_3 & Q_1

- The electrical force on Q_2 must be the same in both cases …
  → it just cancels the weight of Q_2 .

- Since $d_{23} < d_{12}$ the charge of Q_3 must be SMALLER than the charge of Q_1 so that the total electrical force can be the same!!

The World According to Physics 122

- Things -- Bodies and Fields (E,B)
  - Specified by geometry and mass and charge
- Forces
  - Gravity: $\vec{F} = -G\frac{m_1 m_2}{r^2}\hat{r}$



  - Electromagnetic: $\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$

- Space and Time
  - Euclidean with Lorentz Invariance
    - “ordinary space” but can be really really fast...