Welcome to Physics 122

122A: Paul A. Wiggins
122B: Miguel Morales
122C: Arka Majumdar

Content: Electricity & Magnetism

Format: *Active Learning* (Learn from Participation)

Here
- » PreLectures & Checkpoints (FlipIt Physics)
- » Lectures (Presentations, demonstrations & clickers)
- » Homework (Webassign)
- » Tutorials (concepts in depth)
- » Labs (hands-on interactions with the phenomena)

Web and Grading Policy

- Bookmark our Homepage (on canvas).
- Syllabus
  - Links to other aspects of course (FlipIt Physics, 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, FlipIt Physics, Lab work …)

1000 point system

Midterms (best 2 of 3)	35%	350
Final Exam	24%	240
Lab Section	13%	130
Tutorial Section	9%	90
Lecture HW	9%	90
FlipIt Physics	5%	50
Clickers	5%	50

W canvas

Account

Dashboard

Courses

Calendar

Inbox 4

Help

PHYS 122 A > Syllabus

Autumn 2016

Home

Announcements

Assignments

Discussions

Grades

People

Pages

Files

Syllabus

Outcomes

Quizzes

Modules

Conferences

Collaborations

Chat

Attendance

UW Libraries

UW 4.0 Grade Scale

PHYS 122 A: Electromagnetism

Jump to Today

Edit

Instructor:

- Paul A. Wiggins (profw@uw.edu) (122A)
- Office hours: 3-4 PM Tuesday PAB409

Required course textbooks :

- Tipler-Mosca, "Physics for Scientists and Engineers", 6th edition (Custom edition for UW. However, some of you may find a cheaper/used copy of the standard version of the 6th edition and that is fine as well);
- McDermott and Shaffer "Tutorials in Introductory Physics, 2nd ed.";
- PHYS 122 Lab Manual.

Recommended additional readings:

- The Feynman Lectures on Physics, Vol II, by Feynman, Leighton, Sands
- The Flying Circus of Physics, by Jearl Walker

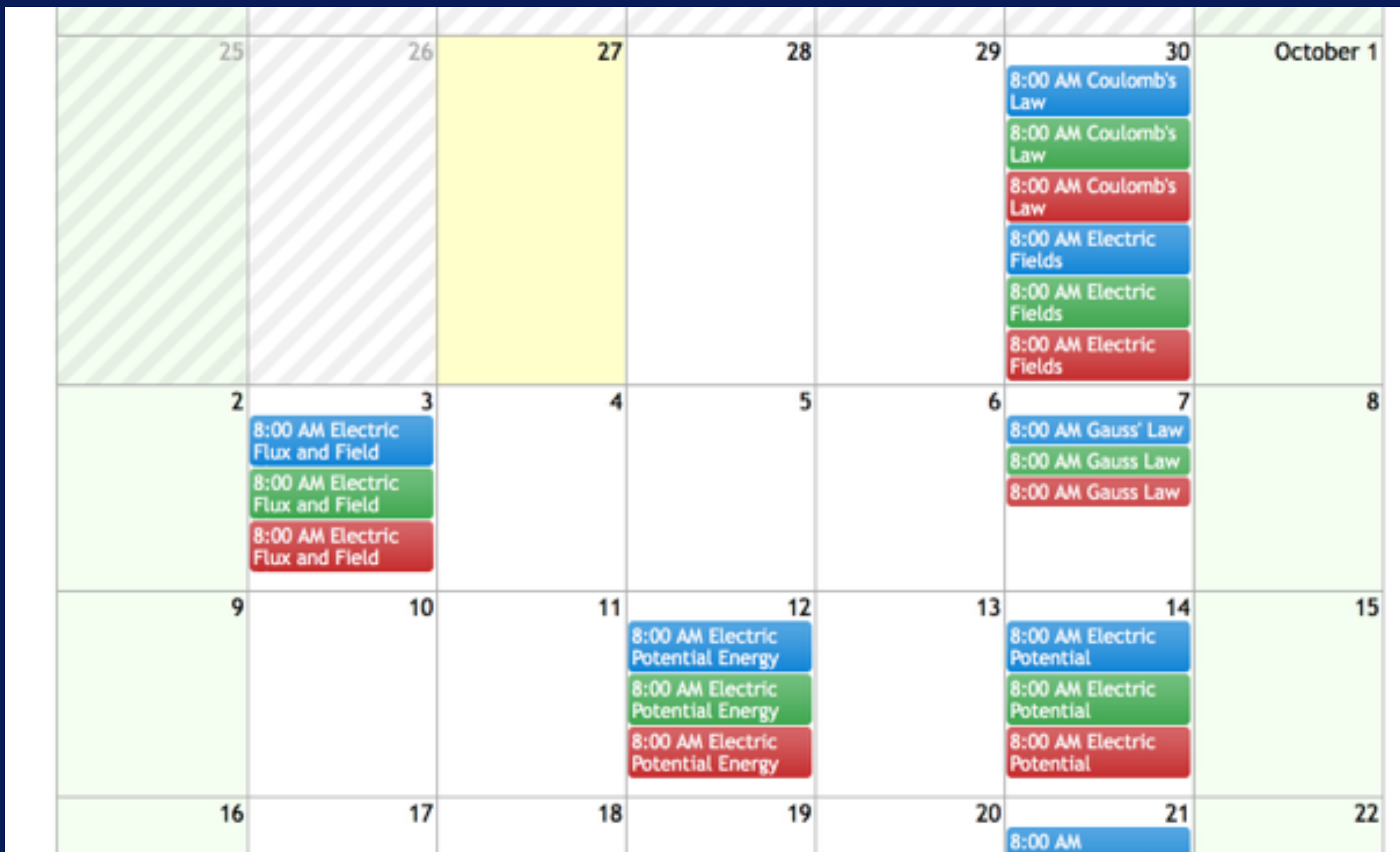
Required Equipment/Packages:

- H-ITT Clicker (Not the same as biology and chemistry)
- FlipIt Physics (Course ID 1579089c)
- WebAssign

Lecture Instructor's Comments

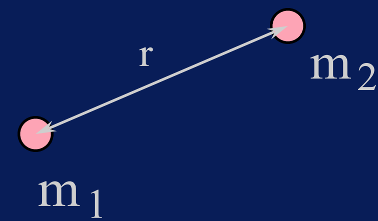
FlipIt Physics

- **I “extended” deadline until Friday**



The World According to Classical Mechanics (Physics 121)

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

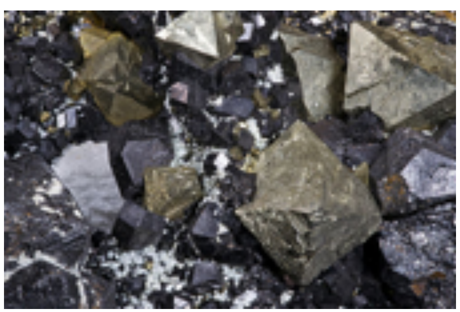


  - Others: Tension, Normal, Friction
- Space and Time
  - Euclidean with Galilean Invariance
    - “ordinary” 3D space; “slow” velocities

E&M: It Wasn't That Easy

- Greeks
  - amber (fossil resin of pine trees) known as νλεκτρον (elektron). eg Plato (4th century BC) "wonderful attracting power of amber and the Heraclean stone"
- Gilbert (De Magnete .. 1600)
  - Electrical effects due to emission of a material effluvium.. no action at a distance
- DuFay (1733)
  - Two distinct electricities: vitreous and resinous
  - Like electricities repel; unlike electricities attract
- Franklin (1750)
  - One electrical fluid: excess $\Rightarrow$ positive (vitreous) deficient $\Rightarrow$ negative (resinous)

A scientific revolution…



- Physics in 1800s:
  - Electricity: Electric fish, lightning & static electricity.
  - Magnetism: Magnetite & the compass
  - Light (& other EM radiation)

… the great unification

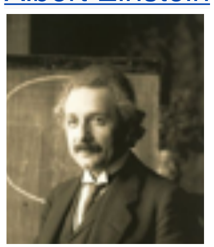
Hans Christian Ørsted

- 1820: Electricity + Magnetism = Electromagnetism

James Clerk Maxwell

- 1865: Electromagnetism + Light

Albert Einstein



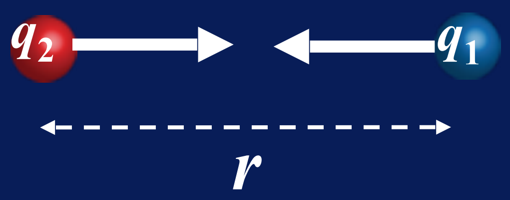
- 1905: Newton → Special Relativity

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

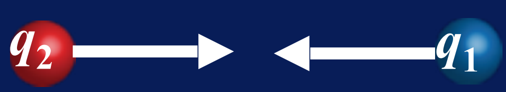
Coulomb's Law:

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:

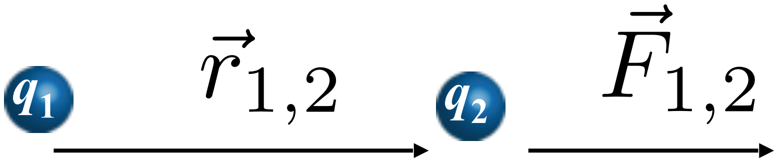


Opposite signs attract

Like signs repel

Coulomb Law

"Direction" (unit vector)



$$\vec{F}_{1,2} = \frac{k\ q_1 q_2}{r_{1,2}^2}\hat{r}_{1,2}$$

$\vec{F}_{1,2}$: Force applied by charge 1 on charge 2

q_1, q_2 : charges of object 1 and 2

k : A physical constant

$\vec{r}_{1,2}$: Displacement vector connecting point 1 to 2

From FlipIt Physics…

The direction of the force.

There are two equations in the book, [(kqq)/(r^2)]r and (kqq)/(r^2). Which one do we use?

$$\vec{F}_{1,2} = \frac{k\ q_1 q_2}{r_{1,2}^2}\hat{r}_{1,2}$$

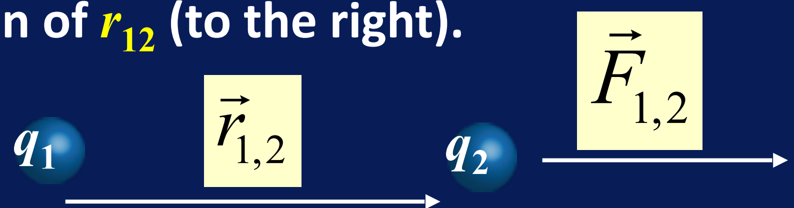
Charles-Augustin de Coulomb

Coulomb Law

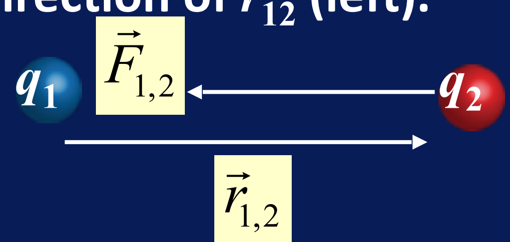
$$\vec{F}_{1,2} = \frac{k\, q_1 q_2}{r_{1,2}^2}\hat{r}_{1,2}$$

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).

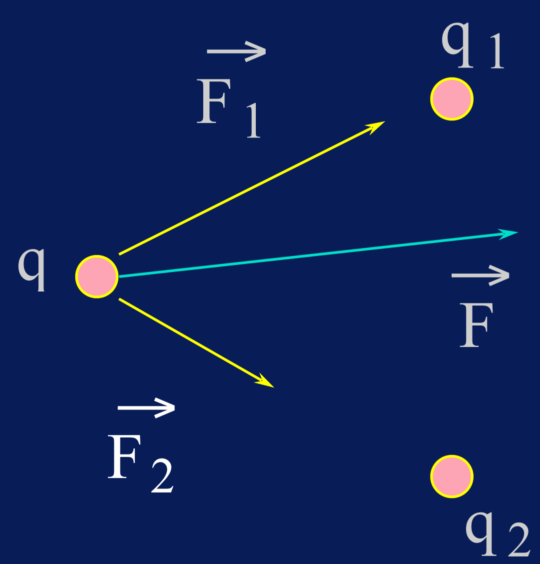


$$k = 8.99 \times 10^9\ \mathrm{N} \cdot \mathrm{m}^2/\mathrm{C}^2$$

Principle of Superposition

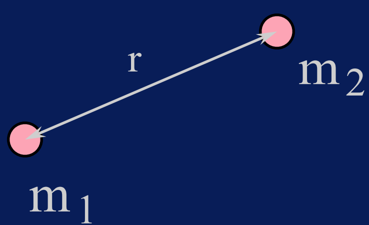
The net force on a charge of the sum of the forces

$$\vec{F}_{i,\mathrm{Net}} = \sum_{j \neq i} \vec{F}_{j,i}$$

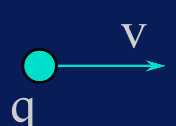


The World According to Physics 122

- 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...

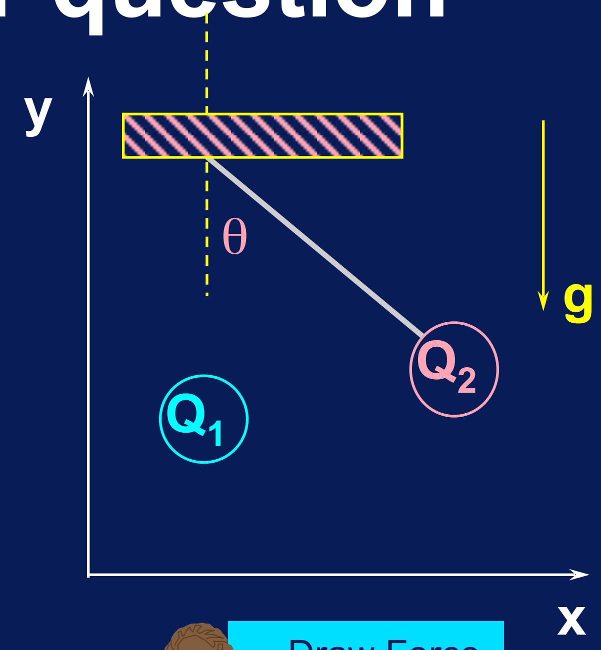
The World According to Physics 122

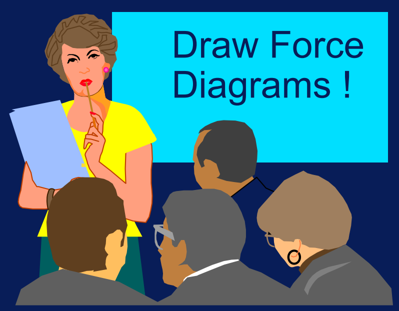
- Bodies and Fields (E,B)
- Forces
- Space and Time

We'll have fun with all of this stuff.
See you next time !

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

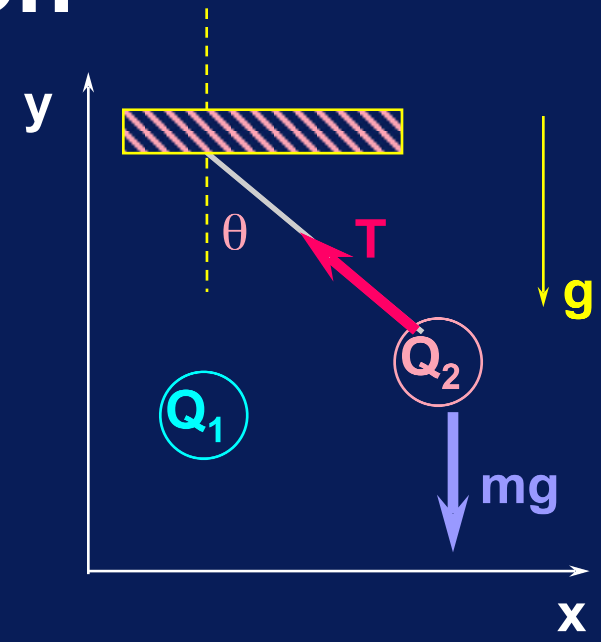
Clicker - solution

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) $F_{Ex} < 0$

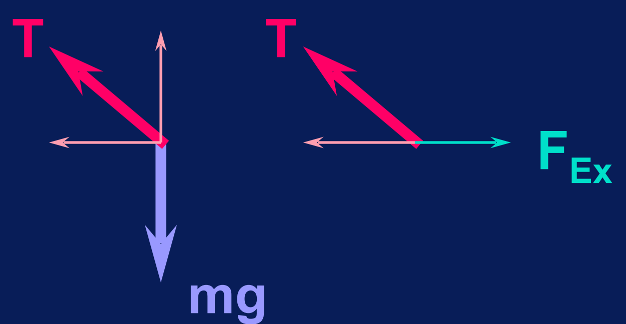
B) $F_{Ex} > 0$

C) Cannot determine sign



Two forces act on Q_2

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



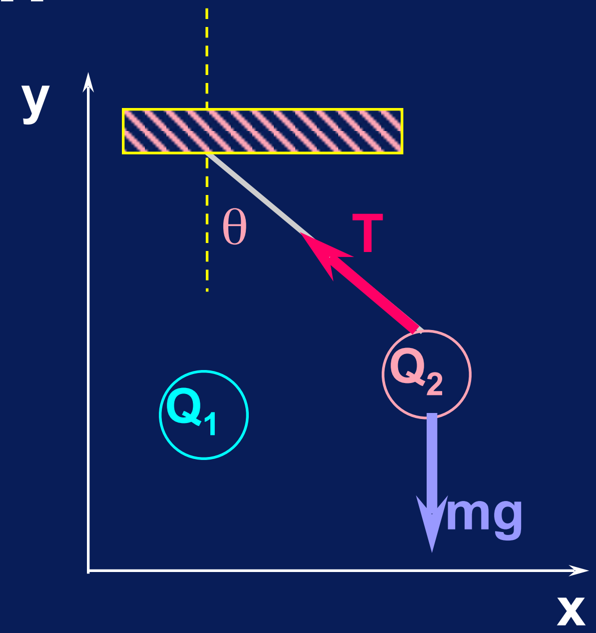
T has an x-component; mg does not.

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



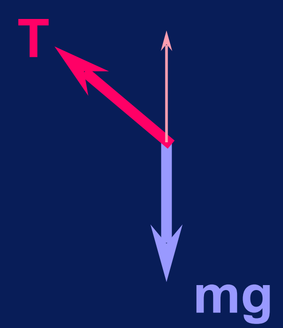
Now consider F_{Ey}

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}.



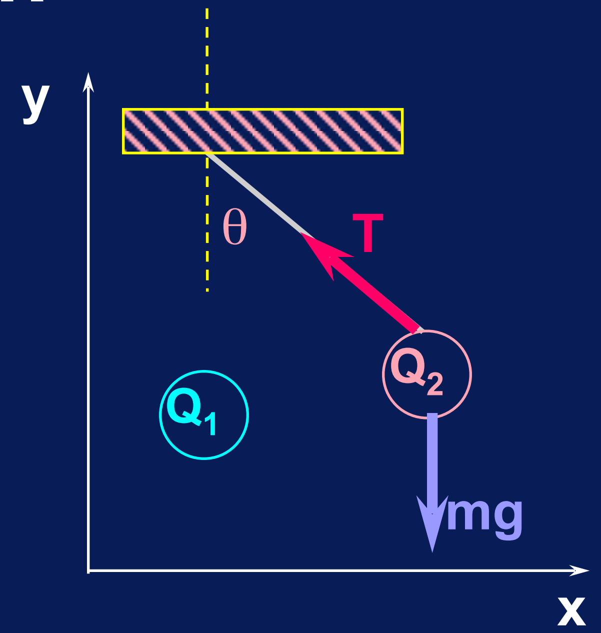
Clicker - solution

Now consider F_{Ey}

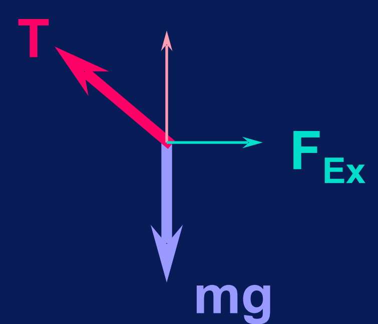
1b: A) $F_{Ey} < 0$

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}.



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

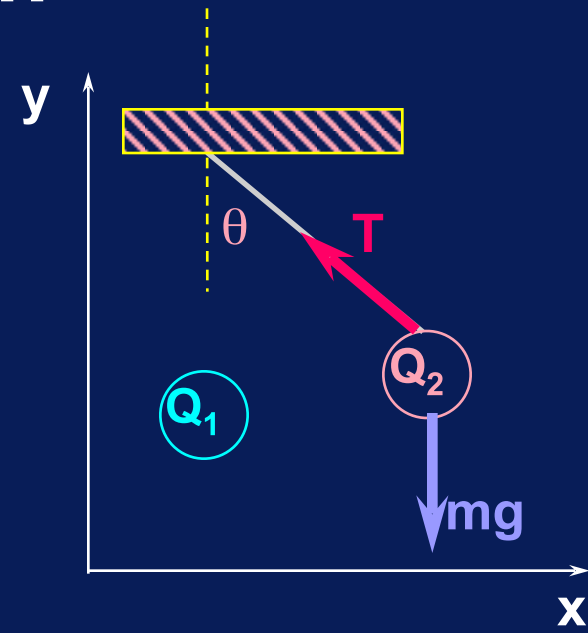
Clicker - solution

Now consider F_{Ey}

1b: A) $F_{Ey} < 0$

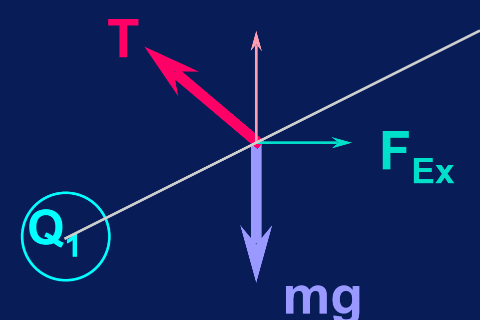
B) $F_{Ey} > 0$

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}.

Remember the Electrical Force has a positive x component…

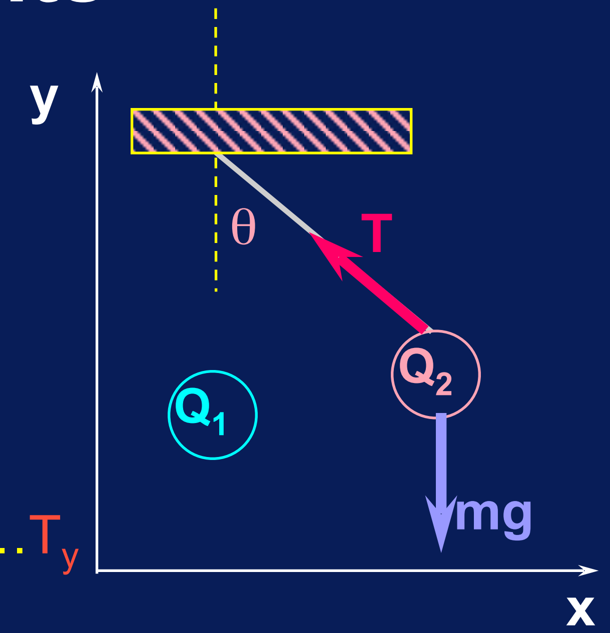


Assume, a *CENTRAL* force. It acts along the white line connecting the two charges

B) $F_{Ey} > 0$

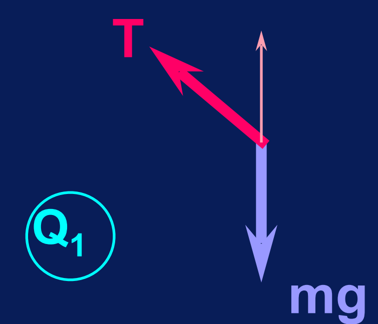
Follow-up thoughts

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

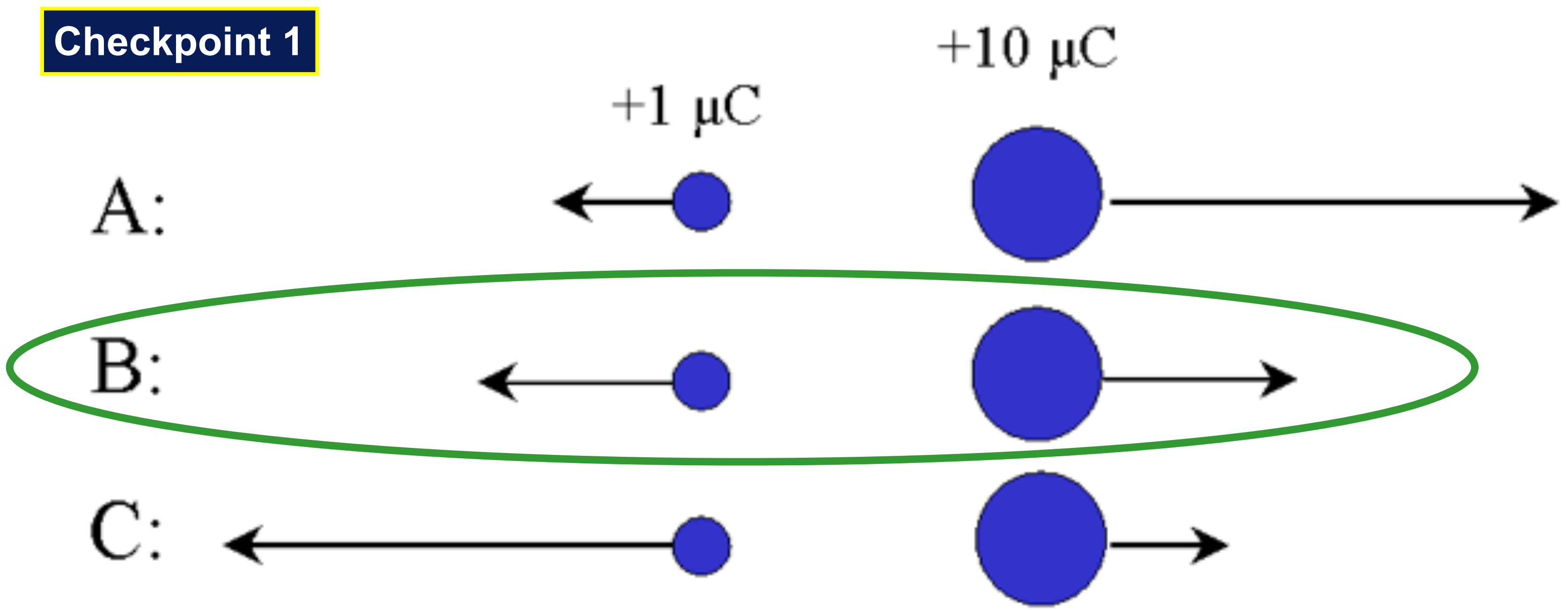
Assumes, some preferred direction in space.

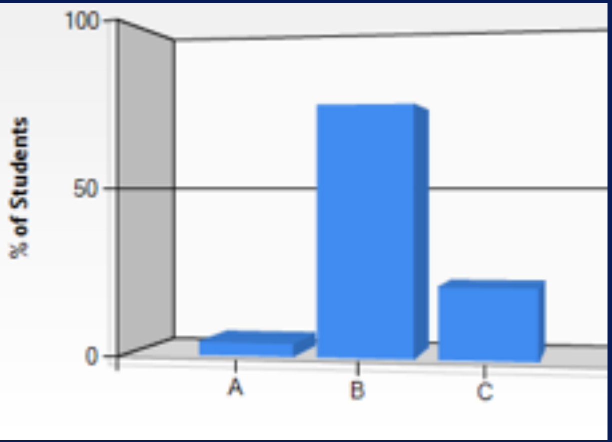
Not likely

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

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:

Checkpoint 1





A) "The Coulomb force is based on k multiplied by q*Q divided by r^2. Therefore, Q would exert a greater force than q and since Q and q have the same signs, they repel each other. . "

B) "due to Newton's 3rd law, the forces acting on the charges will have the same magnitude, but opposite directions."

C) "Since the charge on the right is ten times greater than the charge on the left it will exert a force that is 10 times greater than the other charge"

Clicker setup …

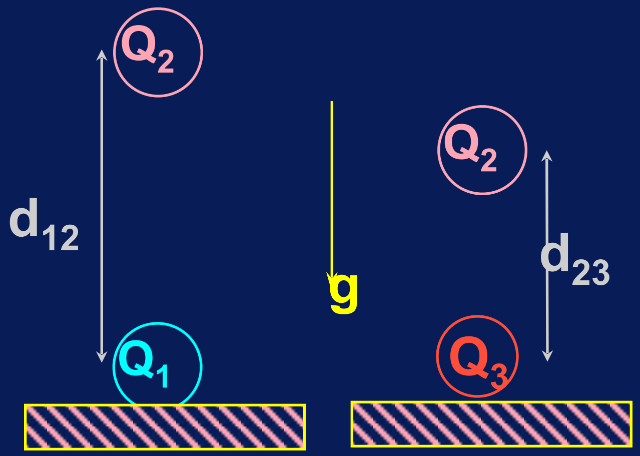
A charged ball Q_1 is fixed to a horizontal surface.

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 Questions

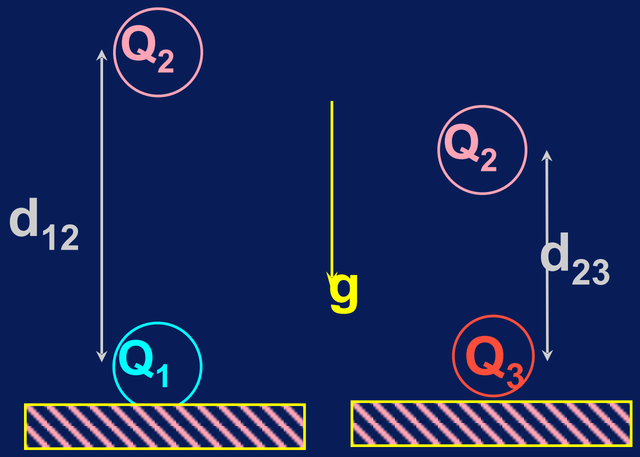
A charged ball Q_1 is fixed to a horizontal surface.

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

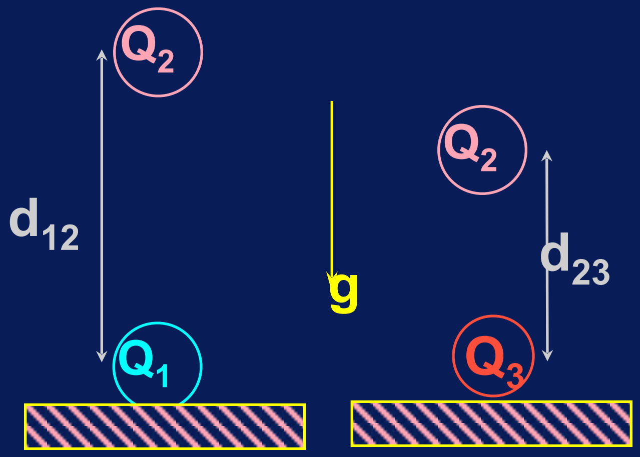
2nd:
A) The magnitude of charge Q_3 < the magnitude of charge Q_1
B) The magnitude of charge Q_3 > the magnitude of charge Q_1
C) Cannot determine relative magnitudes of charges of Q_3 & Q_1

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

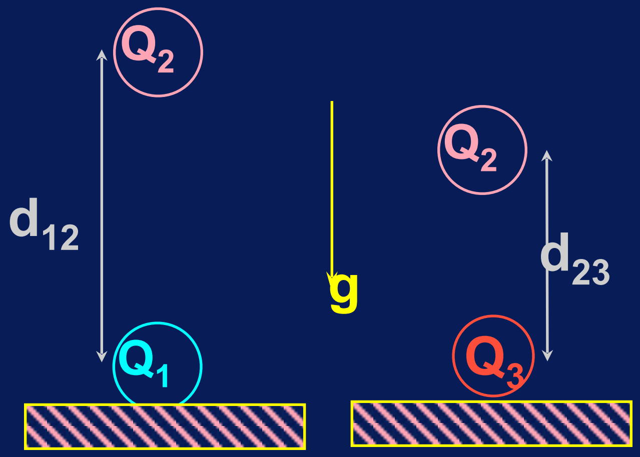
- Equilibrium → the total force on Q_2 must be zero.
- Only known force acting on Q_2 is its weight.
- The electrical force on Q_2 must be directed upward to cancel its weight.
- Therefore, the sign of Q_3 must be the SAME as the sign of Q_1

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!!

CheckPoint

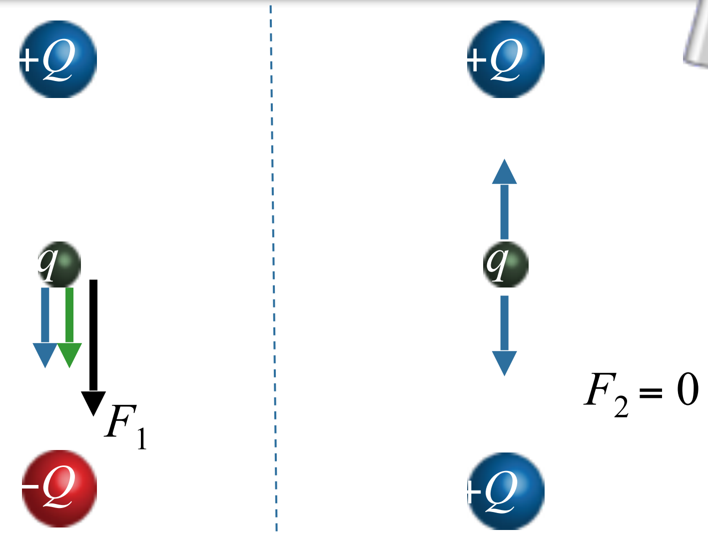
In which Case is the magnitude of the net force on the center charge bigger?

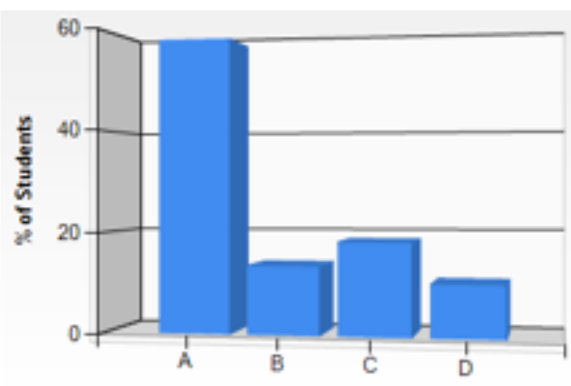
A) Case 1

B) Case 2

C) They are the same

D) The answer depends on the sign of the charge in the center q





A) In case 2, the charges have the same signs so the net force is zero. On the other hands, in Case 1, the charges have different signs. Therefore the net force is not zero

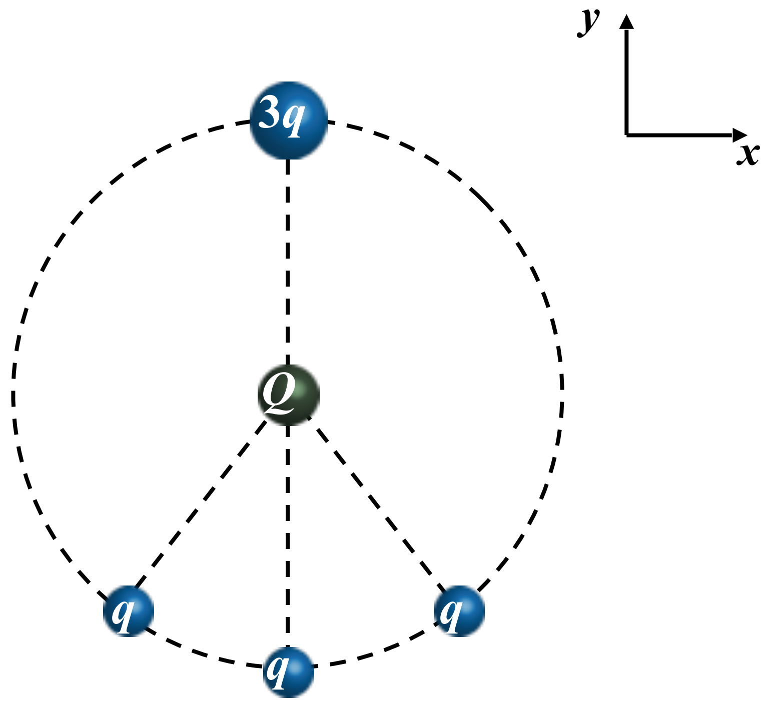
B) The magnitude of the net force on the center would be bigger for case two because both particle is positively charge, compared to the positive and negative which would attract to each other without q and have a net force of 0.

C) Newtons third law explains that all forces must be equal and opposite and therefore they are all the same.

D) Because if q is positive, it has a net force pointing down in case 1 and a net force of zero in case 2; if q is negative, it has a net force pointing up in case 1 and a net force of zero in case 2.

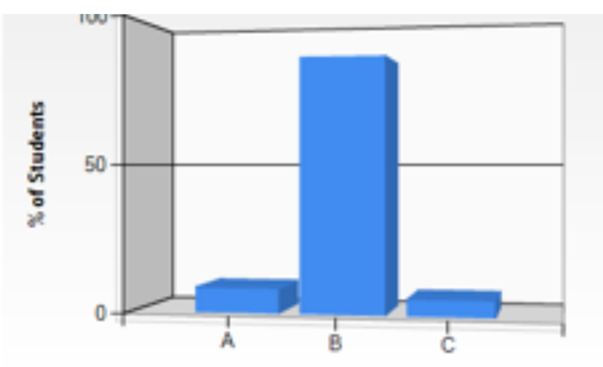
CheckPoint

Four charged particles are placed on a circular ring with radius 3 m as shown below. A particle with charge Q is placed in the center of the ring



Which of the following statements best describes F_X, the x component of the net force on the charge at the origin ?

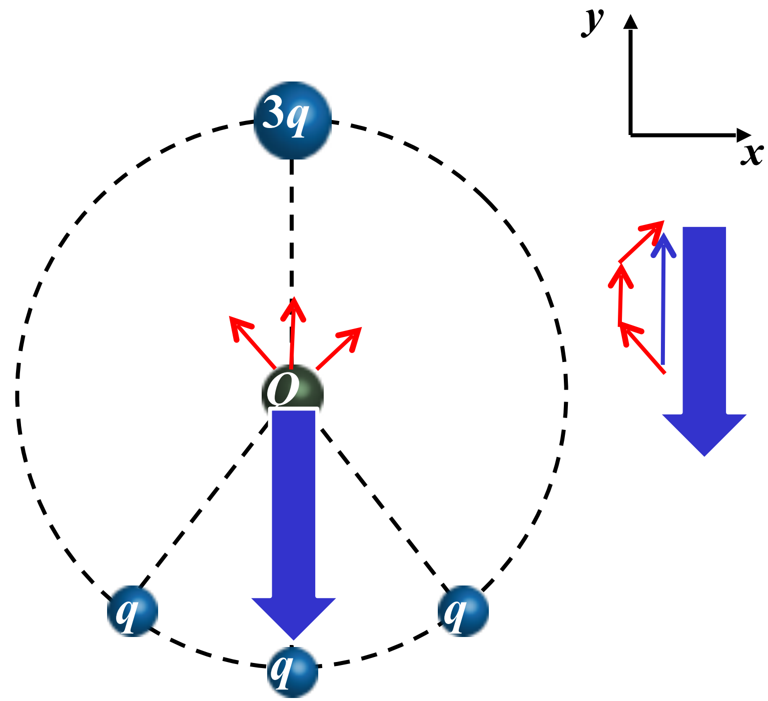
A) $F_x > 0$ B) $F_x = 0$ C) $F_x < 0$



Good job

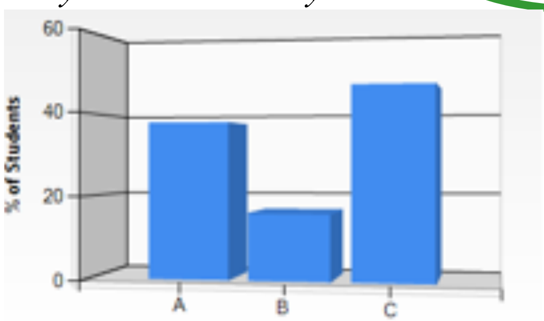
CheckPoint

Four charged particles are placed on a circular ring with radius 3 m as shown below. A particle with charge Q is placed in the center of the ring



What is vertical force on Q?

A) $F_y > 0$ B) $F_y = 0$ C) $F_y < 0$



!!

A) "The single 3q-charged particle has a greater Force on q in the y direction than the three q charged particles."

B) "Since net force is zero, F_y = 0"

C) "The 3q charge is stronger in the y direction compared to the three q charges because 2 of their forces are also directed in the x direction making their impact in the y direction less."