Welcome to Physics 122 **Professor Paul Wiggins** (w/ David Hertzog)

Content: Electricity & Magnetism

Format: Active Learning (Learn from Participation)

- Here PreLectures & Checkpoints (SmartPhysics) > Lectures (presentations, demonstrations, & Clickers) > Homework (problem solving)

 - » Tutorials (concepts in depth)
 - Labs (hands-on interactions with the phenomena) **>>**

Web and Grading Policy

- Bookmark our Homepage.
- <u>http://mtshasta.phys.washington.edu/Phys122Wi15/</u>
- Syllabus
 - Links to other aspects of course (SmartPhysics, 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)	35%	350	
Final Exam	24%	240	
Lab Section	13%	130	
Tutorial Section		9%	90
Lecture HW	9%	90	
SmartPhysics	5%	50	
Clickers	5%	50	

Smart Physics

- I screwed up the email list so...
- I EXTENDED today's deadline until Tuesday morning at 10 am O

Physics 122 C University of Washington									
۵	5	Instructor Link	5 ▽						
							Month View		
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday		
	30	31	January 1	2	3	4	5		
	6	7	8:00 AM Coulomb's Law 8:00 AM Coulomb's Law 8:00 AM Coulomb's Law	9 8:00 AM Electric Fields 8:00 AM Electric Fields 8:00 AM Electric Fields	10	11	12		
	13	14 8:00 AM Electric Flux and Field Lines	15	16 8:00 AM Gauss' Law 8:00 AM Gauss Law	17	18 8:00 AM Electric Potential Energy	19		

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

 m_2

 m_1

- 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.

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



 I820: Electricity + Magnetism = Electromagnetism

James Clerk Maxwell



• 1865: Electromagnetism + Light

Albert Einstein



• 1905: Newton \rightarrow Special Relativity

Fields: A Preview of Physics 122

• Some Demos ...

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.



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





Charles-Augustin de Coulomb

Coulomb's 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).

$$q_1$$
 $\vec{F}_{1,2}$ q_2 $\vec{r}_{1,2}$

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

Coulomb Law



- $\vec{F}_{1,2}$: Force applied by charge I on charge 2
- q_1,q_2 : charges of object I and 2
 - k: A physical constant

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

Principle of Superposition

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



The World According to Physics 122



- Things -- Bodies and Fields (E,B)
 - Specified by geometry and mass and charge
- Forces



 m_1

- Electromagnetic: $\overrightarrow{F} = \overrightarrow{qE} + \overrightarrow{qv} \times \overrightarrow{B}$
- 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

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- 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_{F} 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) $F_{Fx} > 0$

- **Draw Force** Diagrams !
- C) Cannot determine sign of F_{F_x} from this information
- 1b: A) F_{Ev} < 0 B) $F_{Ev} > 0$
 - C) Cannot determine sign of F_{Ev} from this information



A charged ball Q_1 is placed next to another charged ball Q_2 y 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 Q₂

- its weight (mg)
- the tension (T) in the string
- T has an x-component; mg does not.

Equilibrium: the net force on Q₂ 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,







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} .



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...



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



 $F_{Ev} > 0$

B)

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 !



mg

 Q_1

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) "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 Q₃ has the same sign of the charge of Q₁
 B) The charge of Q₃ has the opposite sign as the charge of Q₁
 C) Cannot determine the relative signs of the charges of Q₃ & Q₁
 2nd: A) The magnitude of charge Q₂ < the magnitude of charge Q₄
 - : 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 Q₃ has the same sign of the charge of Q₁
 B) The charge of Q₃ has the opposite sign as the charge of Q₁
 C) Cannot determine the relative signs of the charges of Q₃ & Q₁
- Equilibrium \rightarrow the total force on Q₂ must be zero.
- Only known force acting on Q₂ is its weight.
- The electrical force on Q₂ must be directed upward to cancel its weight.
- Therefore, the sign of Q₃ must be the SAME as the sign of Q₁

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
- 2^{nd} : 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 Q₂ must be the same in both cases ...
 - \rightarrow it just cancels the weight of Q₂.
- Since d₂₃ < d₁₂ the charge of Q₃ must be SMALLER than the charge of Q₁ 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.



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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) $F_x < 0$





/martPhy/ic/

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





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."

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