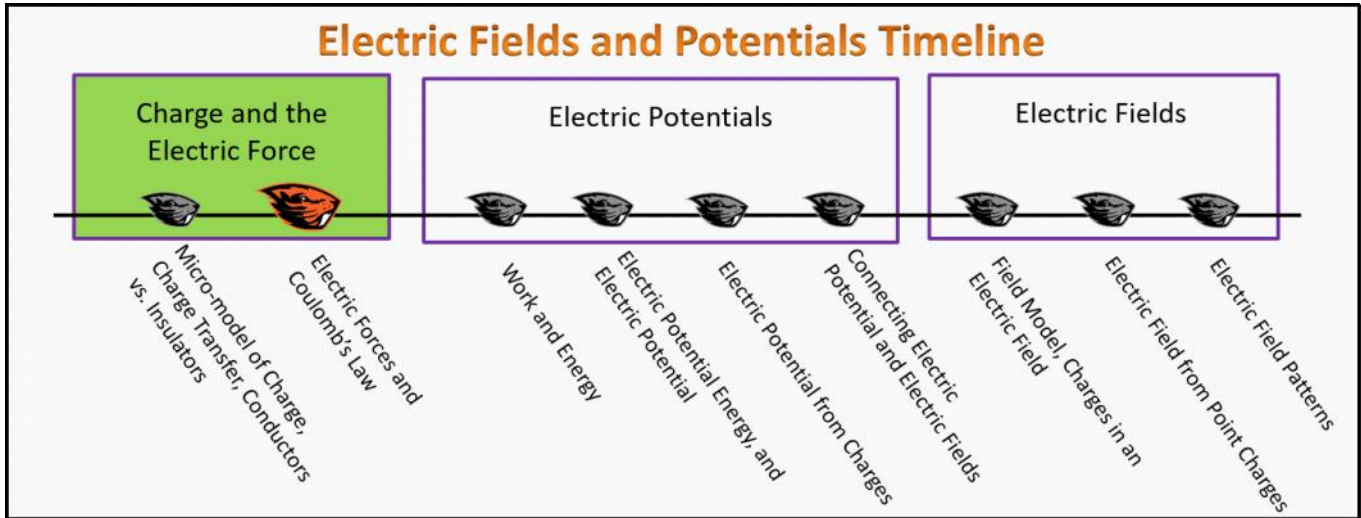


Charge and the Electric Force

Foundation Stage (CF.2.L2)

Lecture 2

Electric Forces and Coulomb's Law



Textbook Chapters (* Calculus version)

- o **BoxSand** :: KC videos ([Charges and the Electric Force](#))
- o **Knight** (College Physics : A strategic approach 3rd) :: 20.1 ; 20.2
- o ***Knight** (Physics for Scientists and Engineers 4th) :: 22.1 ; 22.2 ; 22.3
- o **Giancoli** (Physics Principles with Applications 7th) :: 16-1 ; 16-2 ; 16-3 ; 16-4

Warm up

CF.2.L2-1:

Description: Given forces in the mathematical representation, calculate acceleration.

Learning Objectives: [?] - Can you identify the objectives from the previous lecture, and this lecture, that this question is relevant to?

Problem Statement: Three forces act on an object of mass 2 kg: $\vec{F}^1 = \langle 0,3 \rangle N$; $\vec{F}^2 = \langle 3, -6 \rangle N$; $\vec{F}^3 = \langle -1,2 \rangle N$. Calculate the acceleration of the object.

Selected Learning Objectives

1. Coming soon to a lecture template near you.

Key Terms

- Coulomb's law

Key Equations

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Key Concepts

- Coming soon to a lecture template near you.

Questions

Act I: Electric Force | Coulomb's Law

CF.2.L2-2:

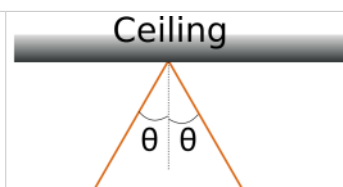
Description: Identify forces acting on an object. (3 minutes)

Learning Objectives: [?]

Problem Statement: Two small pith balls of equal mass and charge are suspended by light strings. The system is in state equilibrium as shown in the figure below.

(a) Which of the following are forces acting on ball 1?

- (1) Gravity
- (2) Tension
- (3) Electric force
- (4) Magnetic force



- (5) Buoyancy
- (6) Normal



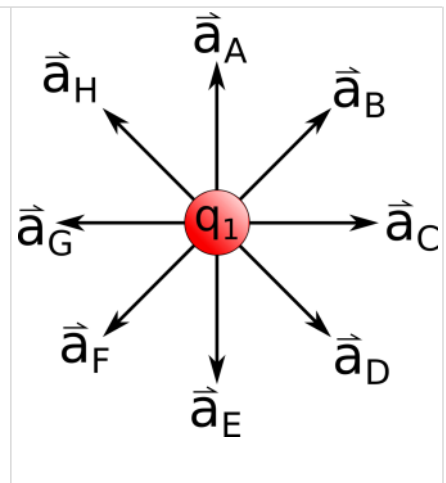
(b) Which of the following represents the FBD for ball 1?

- (1) A
- (2) B
- (3) C
- (4) D

	<div data-bbox="553 401 899 695"> <p>A</p> </div>	<div data-bbox="899 401 1252 695"> <p>B</p> </div>
	<div data-bbox="553 695 899 995"> <p>C</p> </div>	<div data-bbox="899 695 1252 995"> <p>D</p> </div>

(c) If the strings are both cut, at that instant, which vector best represents the direction of acceleration of ball 1?

- (1) A
- (2) B
- (3) C
- (4) D
- (5) E
- (6) F
- (7) G
- (8) H



CF.2.L2-3:

Description: Conceptual question about functional dependence of electric force. (2 minutes)

Learning Objectives: [?]

Problem Statement: Coulomb's law and proportional reasoning.

(a) Two charges, q_1 and q_2 , are initially a distance d apart. If q_1 triples, what happens to the electric force between them?

- (1) Remains the same
- (2) Doubles
- (3) Triples
- (4) Quadruples
- (5) Halves
- (6) Decreases by a factor of $1/3$
- (7) Decreases by a factor of $1/4$

(b) Two charges, q_1 and q_2 , are initially a distance d apart. If q_1 triples and q_2 quadruples what happens to the electric force between them?

- (1) Stays the same
- (2) Triples
- (3) Quadruples
- (4) Increases by a factor of 7
- (5) Increases by a factor of 12
- (6) Increases by a factor of $4/3$
- (7) Decreases by a factor of $3/4$

(c) Two charges, q_1 and q_2 , are initially a distance d apart. If the distance d doubles what happens to the electric force between them?

- (1) Remains the same
- (2) Doubles
- (3) Triples
- (4) Quadruples
- (5) Halves
- (6) Decreases by a factor of $1/3$
- (7) Decreases by a factor of $1/4$

(d) Two charges, q_1 and q_2 , are initially a distance d apart. If the distance d doubles, q_1 triples, and q_2 halves, what happens to the electric force between them?

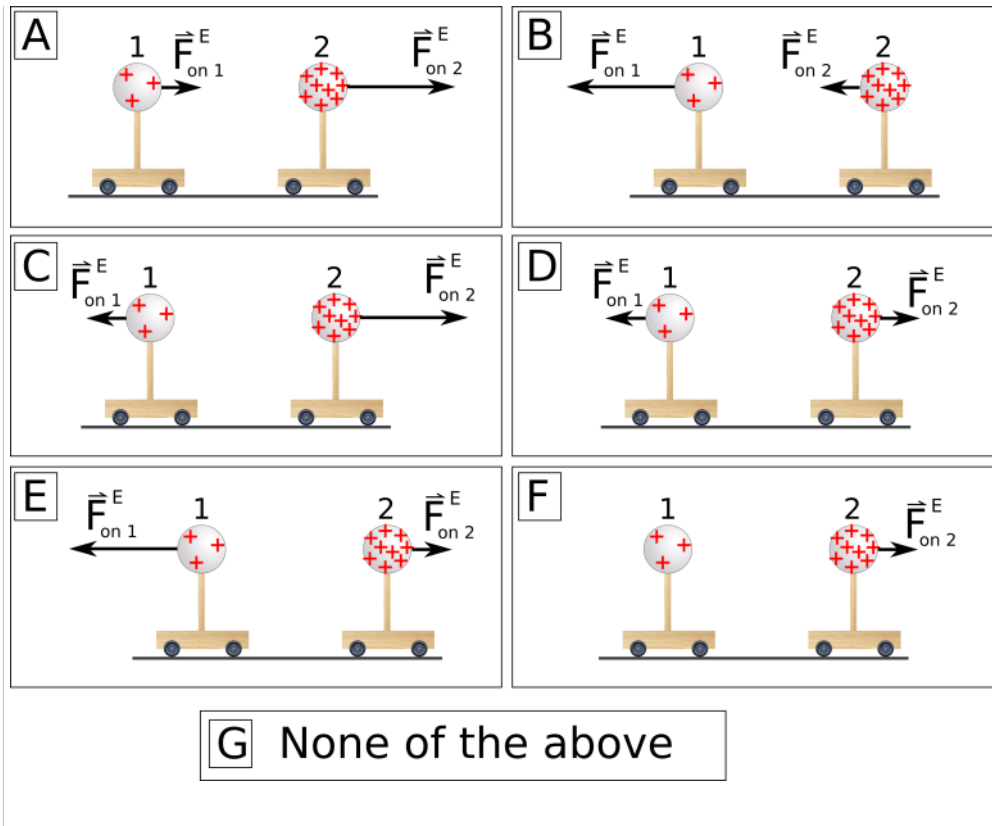
- (1) Remains the same
- (2) Doubles
- (3) Increases by a factor of $8/3$
- (4) Increases by a factor of $4/3$
- (5) Halves
- (6) Decreases by a factor of $3/8$
- (7) Decreases by a factor of $3/4$

CF.2.L2-4:

Description: Identify dominate forces given a system. (3 minutes)

Learning Objectives: [?]

Problem Statement: Two uniformly charged spheres are firmly fastened to and electrically insulated from their bases. The charge on sphere **2** is three times the charge on sphere **1**. Which physical representation correctly shows the magnitude and direction of the electric forces on each sphere?



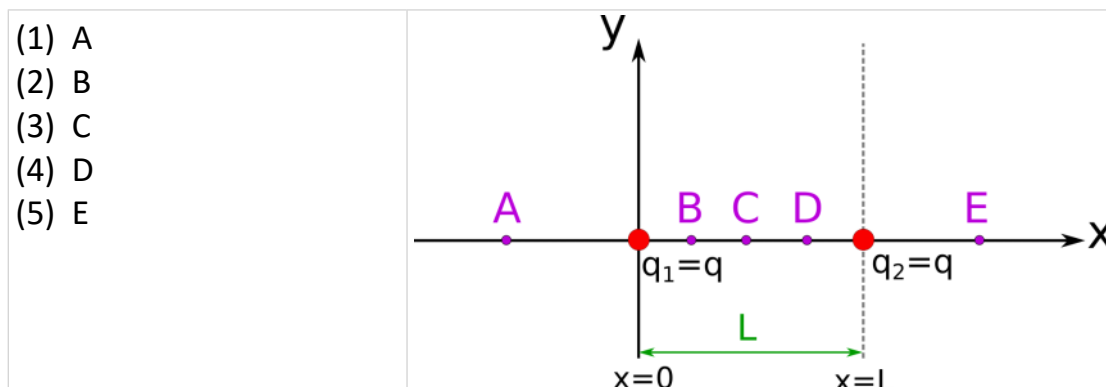
CF.2.L2-5:

Description: Conceptual question identifying features of charges. (4 minutes)

Learning Objectives: [?]

Problem Statement: Two point charges q_1 and q_2 are at $x = 0$ and $x = L$, respectively as seen in the figure below.

(a) If q_1 and q_2 are equal, where could you put a third test charge, q_3 , so that it is in equilibrium?



- (1) A
- (2) B
- (3) C
- (4) D
- (5) E

(b) If q_2 is 4 times that of q_1 , where could you put a third test charge q_3 , so that it is in equilibrium?

<p>(1) A (2) B (3) C (4) D (5) E</p>	<p>The diagram shows a coordinate system with the x-axis horizontal and the y-axis vertical. Two positive charges are located on the x-axis: $q_1 = q$ at $x = 0$ and $q_2 = 4q$ at $x = L$. A green double-headed arrow between $x = 0$ and $x = L$ is labeled L. Five points are marked on the x-axis: A is to the left of $x = 0$; B, C, and D are between $x = 0$ and $x = L$; and E is to the right of $x = L$.</p>
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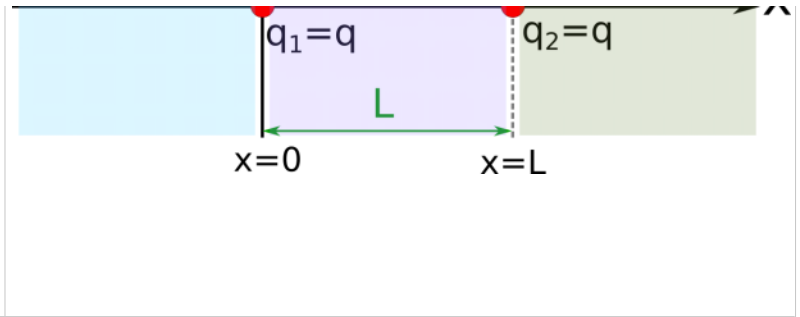
(c) If q_1 and q_2 are equal and positive, which arrow best represents the electric force on a third negative charge q_3 at the location shown in the figure below?

<p>(1) A (2) B (3) C (4) D (5) E (6) F (7) G (8) H</p>	<p>The diagram shows a coordinate system with the x-axis horizontal and the y-axis vertical. Two positive charges are located on the x-axis: $q_1 = q$ at $x = 0$ and $q_2 = -q$ at $x = L$. A green double-headed arrow between $x = 0$ and $x = L$ is labeled L. A negative charge q_3 is located in the first quadrant. Eight force vectors, labeled $\Sigma \vec{F}_A$ through $\Sigma \vec{F}_H$, originate from q_3. Vectors $\Sigma \vec{F}_A$ and $\Sigma \vec{F}_B$ point up and right, $\Sigma \vec{F}_C$ points right, $\Sigma \vec{F}_D$ points down and right, $\Sigma \vec{F}_E$ points down, $\Sigma \vec{F}_F$ points down and left, $\Sigma \vec{F}_G$ points left, and $\Sigma \vec{F}_H$ points up and left.</p>
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(d) Is there a point off axis (in the y-direction in the figure below) where there is a location of total equilibrium if a third charge q_3 is placed there?

<p>(1) Yes, in region A above x-axis. (2) Yes, in region A below x-axis. (3) Yes, in region B, above x-axis.</p>	<p>The diagram shows a coordinate system with the x-axis horizontal and the y-axis vertical. The x-axis is divided into three regions: A (light blue), B (light purple), and C (light green). A red dot is marked on the x-axis at the boundary between region B and region C.</p>
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- (4) Yes, in region B, below x-axis.
- (5) Yes, in region C, above x-axis.
- (6) Yes, in region C, below x-axis.
- (7) No.



CF.2.L2-6:

Description: Rank net charge of systems containing electrons and protons. (4 minutes)

Learning Objectives: [?]

Problem Statement: A snapshot of three charges initially at rest is shown in the figure below. Charge $q_1 = q$, $q_2 = 2q$, and $q_3 = 3q$. Charges q_1 and q_2 lie along the x axis and are 4 meters apart. Charge q_3 is 3 meters directly above q_2 . We eventually wish to find the net electric force on charge q_3 . No other forces other than the electric forces are acting on each charge.

(a) Find the magnitude of the force from q_2 on q_3 , $|\vec{F}_{23}^E|$.

<p>(1) $\frac{3 k q^2}{25} \frac{1}{m^2}$</p> <p>(2) $\frac{6 k q^2}{9} \frac{1}{m^2}$</p> <p>(3) $\frac{6 k q^2}{16} \frac{1}{m^2}$</p>	
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(4) $\frac{5 k q^2}{16} \quad \frac{1}{m^2}$



(5) $\frac{3 k q^2}{16} \quad \frac{1}{m^2}$

(b) Find the magnitude of the force from q_1 on q_3 , $|\vec{F}_{23}^E|$.

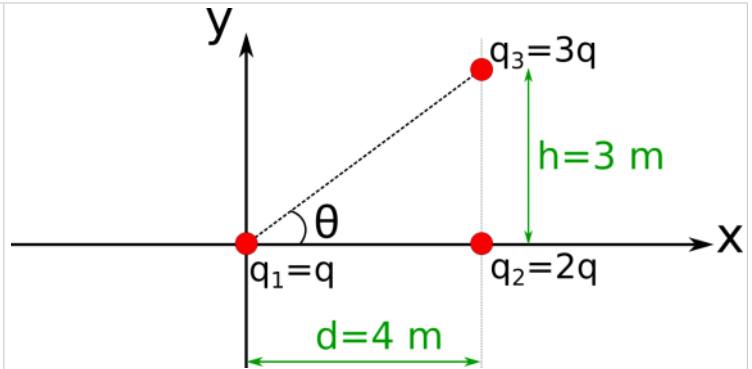
(1) $\frac{3 k q^2}{25} \quad \frac{1}{m^2}$

(2) $\frac{6 k q^2}{9} \quad \frac{1}{m^2}$

(3) $\frac{6 k q^2}{16} \quad \frac{1}{m^2}$

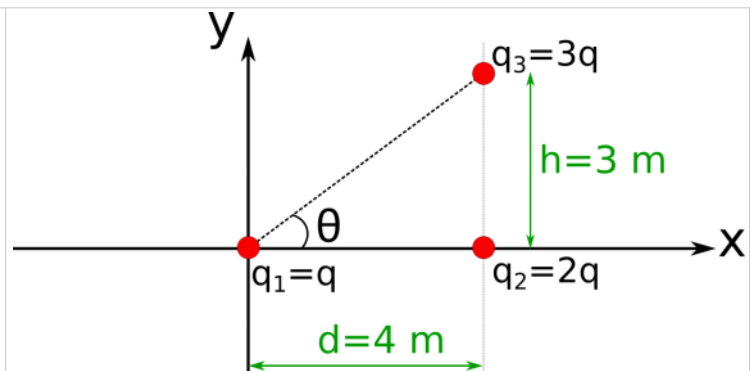
(4) $\frac{5 k q^2}{16} \quad \frac{1}{m^2}$

(5) $\frac{3 k q^2}{16} \quad \frac{1}{m^2}$



(c) Which FBD best represents the electric forces acting on q_3 ?

- (1) A
- (2) B
- (3) C
- (4) D



(d) Find the angle labeled θ .

- (1) 45.0°
- (2) 30.0°
- (3) 60.0°
- (4) 36.9°
- (5) 53.1°

(e) What is the net force acting on q_3 ? Assume a standard coordinate system.

$$(1) \Sigma \vec{F}_{\text{on } q_3} = \frac{6 k q^2}{9} + \frac{3 k q^2}{25}$$

$$(2) \Sigma \vec{F}_{\text{on } q_3} = \frac{6 k q^2}{9} \langle 0, 1 \rangle + \frac{3 k q^2}{25} \langle 0, 1 \rangle$$

$$(3) \Sigma \vec{F}_{\text{on } q_3} = \frac{6 k q^2}{9} \langle 0, 1 \rangle + \frac{3 k q^2}{25} \langle 1, 1 \rangle$$

$$(4) \Sigma \vec{F}_{\text{on } q_3} = \frac{6 k q^2}{9} \langle 0, 1 \rangle + \frac{3 k q^2}{25} \langle 0.8, 0.6 \rangle$$

$$(5) \Sigma \vec{F}_{\text{on } q_3} = \frac{6 k q^2}{9} \langle 0, 1 \rangle + \frac{3 k q^2}{25} \langle 0.6, 0.8 \rangle$$

Act II: Electric Force | Symmetries

CF.2.L2-7:

Description: Calculate number of electrons in a system given net charge. (4 minutes)

Learning Objectives: [?]

Problem Statement: A square with equal side lengths has equal positive charges at each of the vertices. What is the direction of the net force on an electron placed at the center of the square?

- (1) Horizontally to the left.
- (2) Horizontally to the right.
- (3) Vertically upwards.
- (4) Vertically downwards.
- (5) Zero net force.

CF.2.L2-8:

Description: Identify conductors and insulators. (3 minutes)

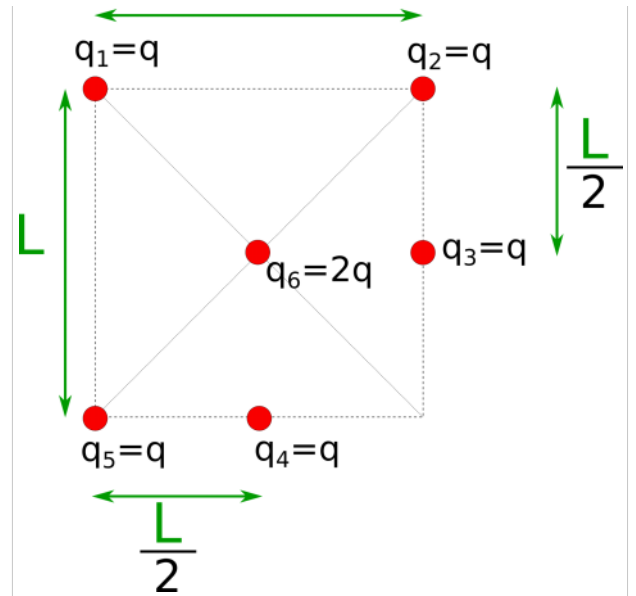
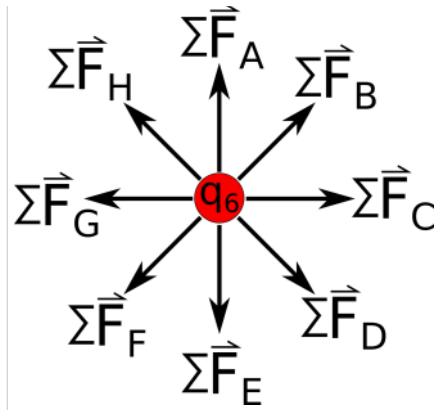
Learning Objectives: [?]

Problem Statement: Five equally charged particles $+q$, are placed on a square as illustrated in the figure below. A 6th charge $+q_6$ is placed at the center of the square. Which arrow best represents the direction of the net electric force acting on the 6th charge?

(1) A

L

- (2) B
- (3) C
- (4) D
- (5) E
- (6) F
- (7) G
- (8) H



Conceptual questions for discussion

1. Coming soon to a lecture template near you.
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Hints

CF.2.L2-1: No hints.

CF.2.L2-2: No hints.

CF.2.L2-3: No hints.

CF.2.L2-4: No hints.

CF.2.L2-5: No hints.

CF.2.L2-6: No hints.

CF.2.L2-7: No hints.

CF.2.L2-8: No hints.