

Charging objects and the force between charges

AP Physics 2 (algebra-based) · Worksheet

Name: _____ Date: _____ Class: _____

These problems train the ideas of AP Physics 2 unit 10 on charge and electric force: counting charge, conservation, charging methods, Coulomb's law and the addition of forces. They run from one-step calculations to multi-part reasoning of the kind used in free-response questions. Use $k = 8.99 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$ and $e = 1.60 \times 10^{-19} \text{ C}$, and write units with every answer.

Level: AP Physics 2 (algebra-based) · **Curriculum:** AP P2 Unit 10

Problem 1 Counting electrons (easy)

A plastic comb in Pune carries an excess of 2.0×10^{13} electrons. Use $e = 1.60 \times 10^{-19} \text{ C}$.

1. State the sign of the charge on the comb.
2. Calculate the magnitude of its charge.
3. Calculate how many electrons must be added to give a charge of $-1.0 \mu\text{C}$.

Problem 2 Charging by friction (easy)

Rubbing with wool transfers 5.0×10^{10} electrons to a plastic ruler.

1. Calculate the charge on the ruler.
2. State the charge on the wool.
3. State the total charge of ruler and wool and name the law.

Problem 3 Attract or repel (easy)

State whether the force between each pair is attractive, repulsive or (for a neutral object) a weak attraction, and give a reason.

1. positive and positive
2. negative and positive
3. negative rod and a neutral metal ball

Problem 4 A simple Coulomb force (easy)

Two small spheres carrying $+4.0 \mu\text{C}$ and $+6.0 \mu\text{C}$ are 0.50 m apart.

1. Calculate the force on each sphere.
2. State whether the force is attractive or repulsive.
3. State the direction of the force on the $+4.0 \mu\text{C}$ sphere.

Problem 5 Unit conversions (easy)

Convert each quantity to the unit shown.

1. $3.5 \mu\text{C}$ to coulombs
2. 250 nC to coulombs
3. 4.0 cm to metres
4. 0.75 mC to microcoulombs

Problem 6 Inverse-square scaling (easy)

Two charges exert a force of 12 N on each other when 2.0 cm apart.

1. Find the force when they are 4.0 cm apart.
2. Find the force when they are 1.0 cm apart.
3. Find the force when they are 6.0 cm apart.

Problem 7 Changing charge and distance (medium)

Two charged spheres exert a force of 0.90 N on each other at a distance r .

1. One charge is doubled and r is tripled. Find the new force.
2. Both charges are doubled and r is halved. Find the new force.
3. One sphere is discharged to zero. State the force.

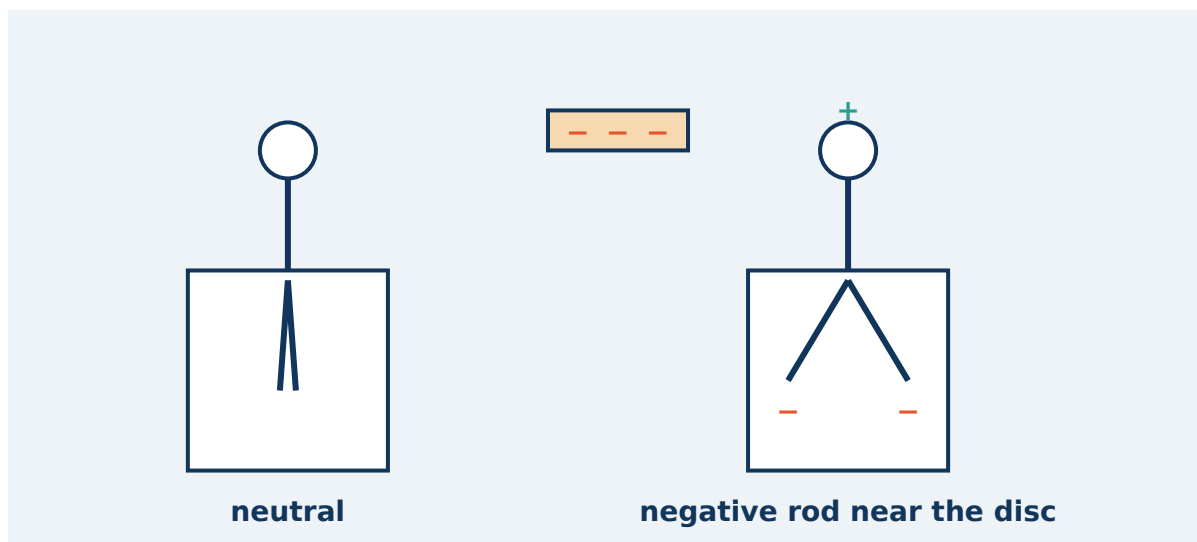
Problem 8 Charging by induction (medium)

Bilal holds a positively charged glass rod near, but not touching, a neutral metal sphere on an insulating stand.

1. Describe how charge moves in the sphere.
2. While the rod stays there, he touches the sphere with a finger for a moment. Describe the flow of charge.
3. He removes the finger and then the rod. State the final sign of the charge on the sphere and explain.

Problem 9 Electroscope (medium)

Mei brings a negative rod near the disc of a neutral gold-leaf electroscope (shown).



A gold-leaf electroscope before and while a negative rod is held near the metal disc.

1. Explain why the leaves move apart.
2. The rod is moved away without touching. Describe what the leaves do and why.
3. Repeat, but the rod touches the disc before it is removed. Predict the leaves afterwards.

Problem 10 Comb and paper (medium)

Emma rubs a plastic comb on her hair and holds it above small pieces of neutral paper. The paper jumps up to the comb.

1. Explain why a neutral piece of paper is attracted.
2. Explain why the attraction is stronger than the repulsion.
3. After a moment some pieces fall off again. Suggest why.

Problem 11 Finding an unknown charge (medium)

Two identical small spheres 0.10 m apart repel each other with a force of 2.7 N.

1. Write an expression for the charge q on each sphere.
2. Calculate q .

Problem 12 Net force on a line (medium)

A $+6.0 \mu\text{C}$ charge sits at $x = 0$ and a $+2.0 \mu\text{C}$ charge sits at $x = 0.40 \text{ m}$. A $-1.0 \mu\text{C}$ charge is placed at $x = 0.10 \text{ m}$.

1. Calculate the force from the $+6.0 \mu\text{C}$ charge.
2. Calculate the force from the $+2.0 \mu\text{C}$ charge.
3. State the net force with direction.

Problem 13 Sharing charge (medium)

Two identical metal spheres carry $+8.0 \mu\text{C}$ and $-2.0 \mu\text{C}$. They are 0.20 m apart.

1. Calculate the force between them.
2. They are touched together and returned to 0.20 m apart. Calculate the new charge on

each.

3. Calculate the new force and say whether it is attractive.

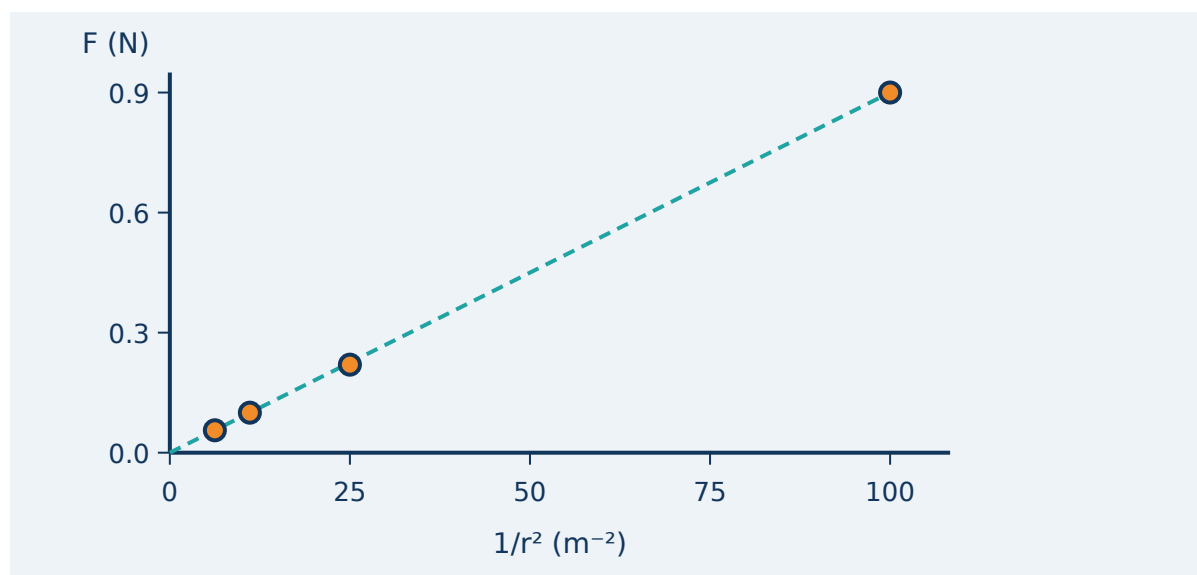
Problem 14 Electric force in hydrogen (medium)

In a hydrogen atom an electron orbits a proton at a distance of 5.3×10^{-11} m. Use $m_e = 9.11 \times 10^{-31}$ kg, $m_p = 1.67 \times 10^{-27}$ kg and $G = 6.67 \times 10^{-11}$ N·m²/kg².

1. Calculate the electric force between them.
2. Calculate the gravitational force between them.
3. Calculate the ratio of the two forces.

Problem 15 Force against $1/r^2$ graph (medium)

Kofi measures the force between two small spheres of equal charge at four separations and plots F against $1/r^2$ (graph shown).



Force between two small charged spheres, plotted against $1/r^2$.

1. Explain why the graph is a straight line through the origin.
2. Find the gradient using the point at $1/r^2 = 100$ m⁻².
3. Calculate the charge on each sphere.

Problem 16 Zero-force point (hard)

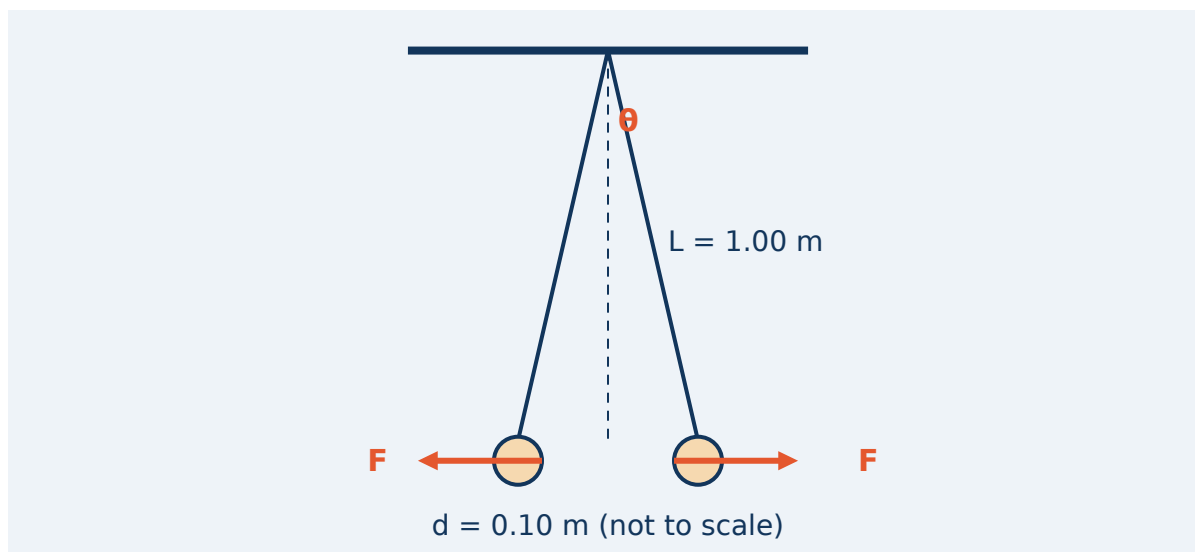
A $+4.0$ μC charge and a $+1.0$ μC charge are fixed 0.30 m apart on a line. A small third charge is placed between them so that it feels no net force.

1. Explain why the third charge must lie between them.
2. Calculate its distance from the $+4.0$ μC charge.
3. State whether the sign of the third charge matters.

Problem 17 Hanging charged balls (hard)

Two identical balls, each of mass 2.0 g, hang from the same point on threads 1.00 m long.

They are given equal charges and settle with their centres 0.10 m apart (shown, not to scale).

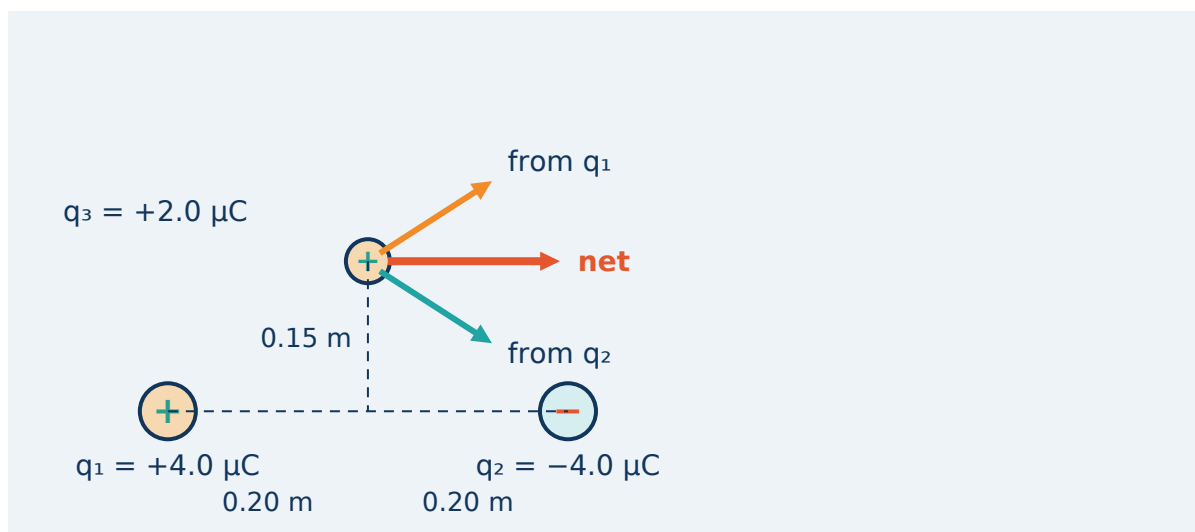


Each ball is in equilibrium under weight, tension and the electric force.

1. Find the angle of each thread to the vertical.
2. Show that the electric force on each ball is $F = mg \tan \theta$ and calculate it.
3. Calculate the charge on each ball.

Problem 18 Forces in two dimensions (hard)

A $+4.0 \mu\text{C}$ charge is at $(0, 0)$ and a $-4.0 \mu\text{C}$ charge is at $(0.40 \text{ m}, 0)$. A $+2.0 \mu\text{C}$ charge q_3 is at $(0.20 \text{ m}, 0.15 \text{ m})$ (shown).



The vertical parts of the two forces cancel, and the horizontal parts add.

1. Show that q_3 is 0.25 m from each of the other charges.
2. Calculate the size of the force each charge exerts on q_3 .
3. Find the net force on q_3 , giving direction.

Problem 19 Hovering sphere (hard)

A fixed sphere carries $+25 \text{ nC}$. A sphere of mass 0.40 g carrying $+25 \text{ nC}$ floats at rest directly above it.

1. Explain why the upper sphere can stay still.
2. Calculate the weight of the upper sphere.
3. Calculate the separation of the spheres.

Problem 20 Unequal charges and motion (hard)

A charge $+Q$ of mass m and a charge $+4Q$ of mass $4m$ are released from rest, close together, in space far from anything else.

1. Compare the sizes of the forces on the two charges and justify your answer.
2. Compare their initial accelerations.
3. Describe the motion of their centre of mass.