Forces on a Bead

Trace electric forces, then calculate their combined effect.

HS-PSII-4.3 "Using Coulomb's law, pictorially and mathematically describe the force on a stationary charge due to other stationary charges. Understand that these forces are equal and opposite as described by Newton's third law and compare and contrast..."

NAME _____ DATE _____

1 READ AND MARK

Read it twice

YOUR JOB Underline each statement that gives a force direction, circle the values and formula used to calculate force, and number the two forces on the center bead 1 and 2.

Three Beads on a Ruler

1. Imagine three tiny charged beads held motionless along a straight ruler. The center bead has 2 nC of positive charge and sits at the zero mark. A bead with 3 nC of positive charge sits 0.30 m to its left, and a bead with 6 nC of negative charge sits 0.60 m to its right. A nanocoulomb, or nC, is 10^{-9} coulomb. Like charges repel; opposite charges attract. To sketch the forces on the center bead, draw an arrow starting at its position for each interaction. Both arrows point right: the left bead repels it, while the right bead attracts it.

2. Coulomb's law gives the size of each force: $F = k|q_1q_2|/r^2$, where $k = 9.0 \times 10^9$ N·m²/C². The charge sizes go in coulombs, and r is the distance between the beads. The left bead pushes the center bead with 6.0×10^{-7} N; the right bead pulls it with 3.0×10^{-7} N. Because both forces point right, their combined force is 9.0×10^{-7} N right. The center bead also pushes the left bead left with 6.0×10^{-7} N. Those equal, opposite forces act on different beads, so they do not cancel.

3. Gravity also acts between objects, but it depends on mass rather than charge. For a pair of protons at the same separation, electric repulsion is about 10^{36} times stronger than gravitational attraction. Both forces weaken with the square of distance: doubling separation makes either force one-fourth as strong. Unlike gravity between ordinary masses, which always attracts, the electric force can attract or repel. In the bead setup, the force that the center bead exerts on the right bead points left and has a size of 3.0×10^{-7} N. This is another equal-and-opposite pair acting on different beads.

2 ANSWER WITH EVIDENCE

Use the passage

1. If you sketch the forces on the center bead, which way does each arrow point? Explain each direction using the beads' charges.

2. Use Coulomb's law to show how the right bead's force on the center bead is calculated.

3. What force does the center bead exert on the right bead? Why does this force not cancel a force on the center bead?

4. For two protons at the same separation, compare electric force with gravity in direction and strength. What happens to both forces if the separation doubles?

3 YOUR TURN

Your own words

On a new ruler, place a bead with 4 nC of positive charge at zero, a bead with 2 nC of negative charge 0.20 m left, and a bead with 8 nC of negative charge 0.40 m right. Sketch and label both force arrows on the center bead; calculate each force and the net force, then identify the equal-and-opposite partner to the force from the left bead.

ANSWER KEY

Forces on a Bead

PART 1 · READ AND MARK

Underline each statement that gives a force direction, circle the values and formula used to calculate force, and number the two forces on the center bead 1 and 2. Accept any marking that follows this job and points at the right text.

PART 2 · ANSWERS

#	QUESTION	ANSWER
1	If you sketch the forces on the center bead, which way does each arrow point? Explain each direction using the beads' charges.	**Both arrows point right. The positive left bead repels the positive center bead, and the negative right bead attracts it.**
2	Use Coulomb's law to show how the right bead's force on the center bead is calculated.	**$F = (9.0 \times 10^{9})(2 \times 10^{-9})(6 \times 10^{-9})/(0.60)^{2} = 3.0 \times 10^{-7}$ N.**
3	What force does the center bead exert on the right bead? Why does this force not cancel a force on the center bead?	**It exerts 3.0×10^{-7} N left on the right bead. The equal-and-opposite forces act on different beads.**
4	For two protons at the same separation, compare electric force with gravity in direction and strength. What happens to both forces if the separation doubles?	**Electric force repels and is about 10^{36} times stronger; gravity attracts. Doubling the separation makes each force one-fourth as strong.**

PART 3 · YOUR TURN (SAMPLE ANSWER)

Sketch: the center bead has an arrow pointing left toward the left bead and an equal-length arrow pointing right toward the right bead. Left force = $(9.0 \times 10^{9})(4 \times 10^{-9})(2 \times 10^{-9})/(0.20)^{2} = 1.8 \times 10^{-6}$ N left. Right force = $(9.0 \times 10^{9})(4 \times 10^{-9})(8 \times 10^{-9})/(0.40)^{2} = 1.8 \times 10^{-6}$ N right. Net force = 0 N. The center bead pulls the left bead right with 1.8×10^{-6} N.

Accept equivalent calculations and sketches with two equal-length arrows pointing in opposite directions from the center bead. Distinguish the two forces that cancel on the center bead from a Newton's third-law pair acting on different beads.