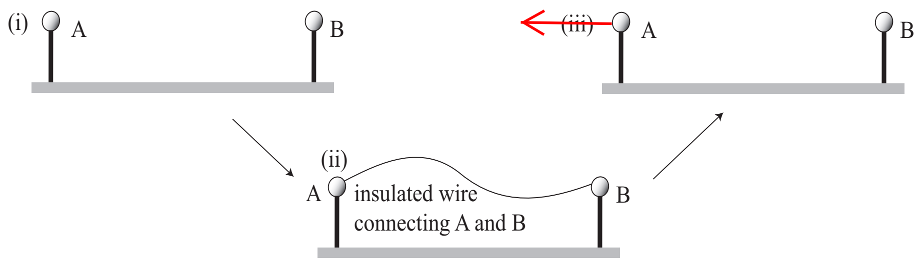
Name: ____________________ **Section:** __________ **Score:** __________/20

1 Very small identical metal spheres A and B are on glass stands placed as in the figure below (i). Initially, A has net charge nQ and B Q. The Coulomb force acting on charge A is $\boldsymbol{F}$. Then, A and B are connected by an uncharged (and insulated) metal wire as (ii) in the figure. After the wire is removed (iii), the force acting on charge A becomes $\boldsymbol{F}'$. The distance between the small spheres is kept constant. The ratio of the horizontal component (let us call it the x-component) of the forces is given as $F_x/F'_x = -3$.



(a) What is a very fundamental law (property) of charges we need to determine the charges on the spheres in (iii)? [2].

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conservation of charge
Thus (n+1)Q/2 is on A and B, respectively.
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(b) Find the initial ratio of the charge n (an integer) (no justification, no credit!) [6]

Coulomb's law

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The x-component of the forces are:
Before: F_x = k(nQ)(Q)/r^2, where r is the distance between A and B,
After: F'_x = k(n+1)^2 Q^2/4r^2,
so
F/F' = 4n/(n+1)^2 = -3.
or
 3 n^2 +10 n +3 = (3n + 1)(n + 3) = 0.
This implies n = -3.
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If you write down this , you get almost a full score.

(c) Draw the direction of the Coulomb force acting on A in (iii) in the figure above [2]

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The force must be repulsive.
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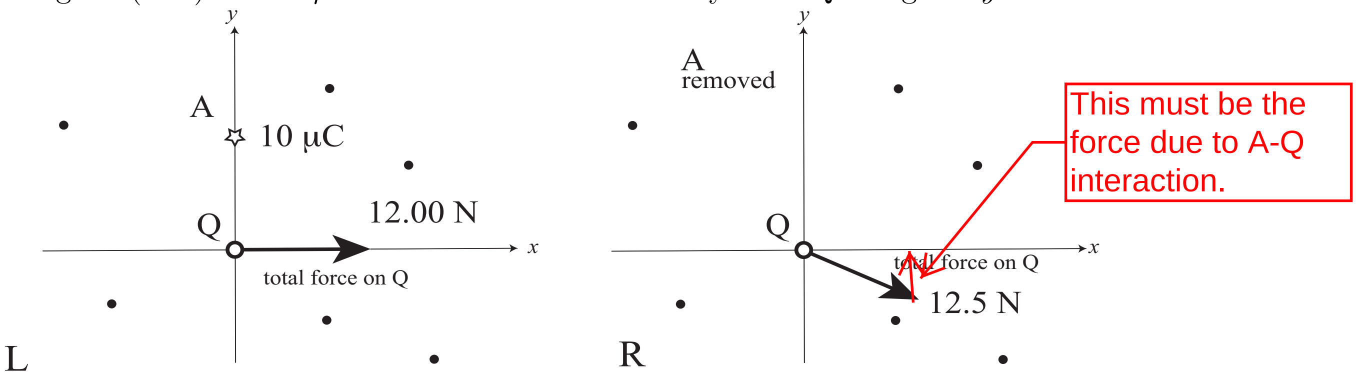
2. There are several charges on a plane as shown (as dots and a star) in the figure below left (L). The total electrostatic force acting on charge Q at the origin is 12 N in the $+x$-direction. The charge A (star) is $+10$ μC and is located 30 cm away from Q along the y-axis.



(a) When the charge at Q is doubled, what is the total electrostatic force acting on Q? [2]

Superposition + Coulomb

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The total force is proportional to Q, so 24 N
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When the charge A is removed (situation R in the figure above) but all the remaining charges are kept intact, the total electrostatic force acting on charge Q is 12.37 N with the direction in the figure.

(b) What is the sign of charge Q? You must state justification of your answer. [3]

Superposition + Coulomb

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The red arrow must be the force on Q due to A.
Therefore, Q is attracted to A.  A is positive, so Q
must be negative.
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(c) What is the magnitude of charge Q? You must state justification of your answer. [5]

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The magnitude of the red arrow is, thanks to Pythagoras' theorem
sqrt(12.5^2 - 12^2) = 3.5 N.

Using Coulomb's force (magnitude) formula F = kQQ'/r^2, we get
3.5 = 9x10^9 x Q x (10x10^{-6})/0.3^2, BUT never do this.  Solve Q first:
Q = Fr^2/kQ'.
Therefore,
      Q = 3.5 x (0.3^2)/(9x10^9)(10x10^{-6}) = 3.5 x 10^{-2-9+5}
        = 3.5 x10^{-6}
or 3.5 microC. (The charge is - 3.5 microC.)
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