Name:______________________________ Class:___________________ Date:___________________

Electric Forces and Fields

Problem C

EQUILIBRIUM PROBLEM

In 1955, a water bore that was 2231 m deep was drilled in Montana. Consider two charges, q_2 = 1.60 mC and q_1, separated by a distance equal to the depth of the well. If a third charge, q_3 = 1.998 μC, is placed 888 m from q_2 and is between q_2 and q_1, this third charge will be in equilibrium. What is the value of q_1?

SOLUTION

1. **DEFINE**

Given:

$q_2 = 1.60 \text{ mC} = 1.60 \times 10^{-3} \text{ C}$

$q_3 = 1.998\ \mu\text{C} = 1.998 \times 10^{-6} \text{ C}$

$r_{3,2} = 888 \text{ m}$

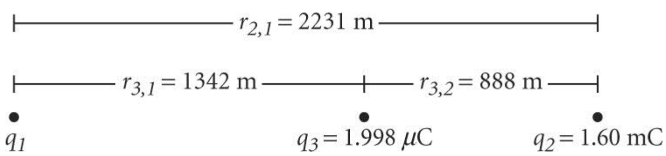
$r_{3,1} = 2231 \text{ m} - 888 \text{ m} = 1342 \text{ m}$

$r_{2,1} = 2231 \text{ m}$

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

Unknown: $q_1 = ?$

Diagram:



2. **PLAN** **Choose the equation(s) or situation:** The force exerted on q_3 by q_2 will be opposite the force exerted on q_3 by q_1. The resultant force on q_3 must be zero in order for the charge to be in equilibrium. This indicates that $F_{3,1}$ and $F_{3,2}$ must be equal to each other.

$$F_{3,1} = k_C\left(\frac{q_3 q_1}{(r_{3,1})^2}\right) \text{ and } F_{3,2} = k_C\left(\frac{q_3 q_2}{(r_{3,2})^2}\right)$$

$$F_{3,1} = F_{3,2}$$

$$k_C\left(\frac{q_3 q_1}{(r_{3,1})^2}\right) = k_C\left(\frac{q_3 q_2}{(r_{3,2})^2}\right)$$

Rearrange the equation(s) to isolate the unknown(s): q_3 and k_C cancel.

$$q_1 = q_2\left(\frac{r_{3,1}}{r_{3,2}}\right)^2$$

3. **CALCULATE** **Substitute the values into the equation(s) and solve:**

$$q_1 = (1.60 \times 10^{-3} \text{ C})\left(\frac{1342 \text{ m}}{888 \text{ m}}\right)^2 = 3.65 \times 10^{-3} \text{ C}$$

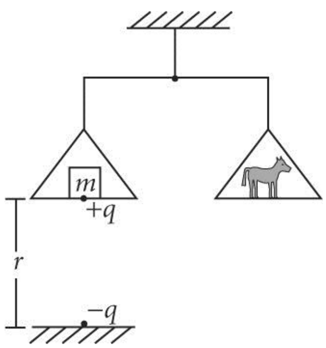
$$q_1 = 3.65 \text{ mC}$$

Name:______________________________ Class:__________________ Date:__________________

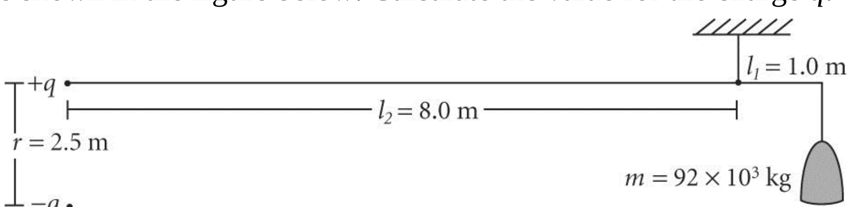
4. EVACULATE Because q_1 is a little more than twice as large as q_2, the third charge (q_3) must be farther from q_1 for the forces on q_3 to balance.

ADDITIONAL PRACTICE

1. **Hans Langseth's beard measured 5.33 m in 1927. Consider two charges, q_1 = 2.50 nC and an unspecified charge, q_2, are separated 5.33 m. A third charge of 1.0 nC is placed 1.90 m away from q_1. If the net electric force on this third charge is zero, what is q_2?**
2. **The extinct volcano Olympus Mons, on Mars, is the largest mountain in the solar system. It is 6.00×10^2 km across and 24 km high. Suppose a charge of 75 mC is placed 6.0×10^2 km from aN unspecified charge. If a third charge of 0.10 mC is placed 24 km from the first charge and the net electric force on this third charge is zero, how large is the unspecified charge?**
3. **Earth's mass is about 6.0×10^{24} kg while the moon's mass is 7.3×10^{22} kg. What equal charges must be placed on Earth and the moon to make the net force between them zero?**
4. In 1974, an emerald with a mass of 17.23 kg was found in Brazil. Suppose you want to hang this emerald on a string that is 80.0 cm long and has a breaking strength of 167.6 N. To hang the jewel safely, you remove a certain charge from the emerald and place it at the pivot point of the string. What is the minimum possible value of this charge?
5. Little Pumpkin, a miniature horse owned by J. C. Williams, Jr., of South Carolina, had a mass of about 9.00 kg. Consider Little Pumpkin on a twin-pan balance. If the mass on the other pan is 8.00 kg and *r* equals 1.00 m, what equal and opposite charges must be placed as shown in the diagram below to maintain equilibrium?



6. The largest bell that is in use today is in Mandalay, Myanmar, formerly called Burma. Its mass is about 92×10^3 kg. Suppose the bell is supported in equilibrium as shown in the figure below. Calculate the value for the charge *q*.



7. **In more than 30 years, Albert Klein, of California, drove 2.5×10^6 km in one automobile. Consider two charges, $q_1 = 2.0$ C and $q_2 = 6.0$ C, separated by Klein's total driving distance. A third charge, $q_3 = 4.0$ C, is placed on the line connecting q_1 *and* q_2. How far from q_1 should q_3 be placed for q_3 to be in equilibrium?**
8. **A 55 μC charge and a 137 μC charge are separated by 87 m. Where must a 14 μC charge be placed between these other two charges in order for the net electric force on it to be zero?**
9. **In 1992, a Singapore company made a rope that is 56 cm in diameter and has an estimated breaking strength of 1.00×10^8 N. Suppose this rope is used to connect two strongly charged asteroids in space. If the charges of the asteroids are $q_1 = 1.80 \times 10^4$ C and $q_2 = 6.25 \times 10^4$ C, what is the minimum length that the rope can have and still remain intact? Neglect the effects of gravity.**
10. The CN Tower, in Toronto, Canada, is 553 m tall. Suppose two balls, each with a mass of 5.00 kg and a charge of 40.0 mC, are placed at the top and bottom of the tower, respectively. The ball at the top is then dropped. At what height is the acceleration on the ball zero?
11. *Mycoplasma* is the smallest living organism known. Its mass has an estimated value of 1.0×10^{-16} g. Suppose two specimens of this organism are placed 1.0 m apart and one electron is placed on each. If the medium through which the *Mycoplasma* move exerts a resistive force on the organisms, how large must that force be to balance the force of electrostatic repulsion?
12. The parasitic wasp *Carapractus cinctus* has a mass of 5.0×10^{-6} kg, which makes it one of the smallest insects in the world. If two such wasps are given equal and opposite charges with an absolute value of 2.0×10^{-15} C and are placed 1.00 m from each other on a horizontal smooth surface, what extra horizontal force must be applied to each wasp to keep it from sliding? Take into account both gravitational and electric forces between the wasps.
13. **In 1995, a single diamond was sold for more than $16 million. It was not the largest diamond in the world, but its mass was an impressive 20.0 g. Consider such a diamond resting on a horizontal surface. It is known that if the diamond is given a charge of 2.0 μC and a charge of at least −8.0 μC is placed on that surface at a distance of 1.7 m from it, then the diamond will barely keep from sliding. Calculate the coefficient of static friction between the diamond and the surface.**