

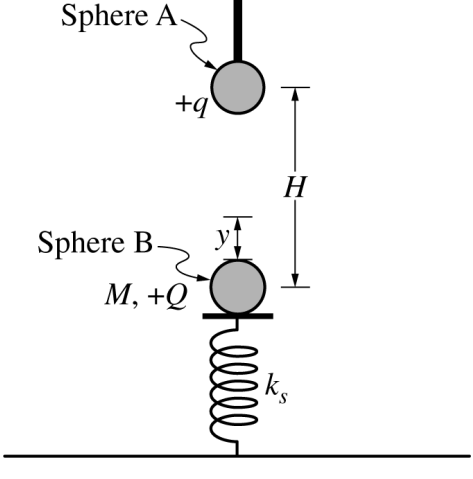
PHYSICS C: ELECTRICITY AND MAGNETISM

SECTION II

Time—45 minutes

3 Questions

Directions: Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part.



Note: Figure not drawn to scale.

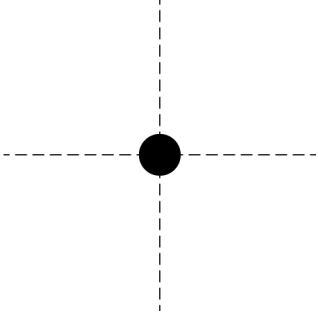
Students perform an experiment to determine the value of vacuum permittivity ϵ_0 . Sphere A is nonconducting with charge $+q$ and is attached to an insulating rod. Sphere B is nonconducting with charge $+Q$, and has mass M . Sphere B rests on an insulating platform of negligible mass that is attached to a vertical ideal spring with spring constant k_s . Sphere B and the spring are initially at rest.

Sphere A is then brought near Sphere B without touching. When the centers of the spheres are separated by a vertical distance H , the spring has been compressed a distance y , as shown in the figure. The students measure y for different values of H .

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Continue your response to **QUESTION 1** on this page.

(a) On the following dot that represents Sphere B in the figure on the previous page, draw and label the forces (not components) that are exerted on Sphere B. Each force must be represented by a distinct arrow starting on, and pointing away from, the dot.

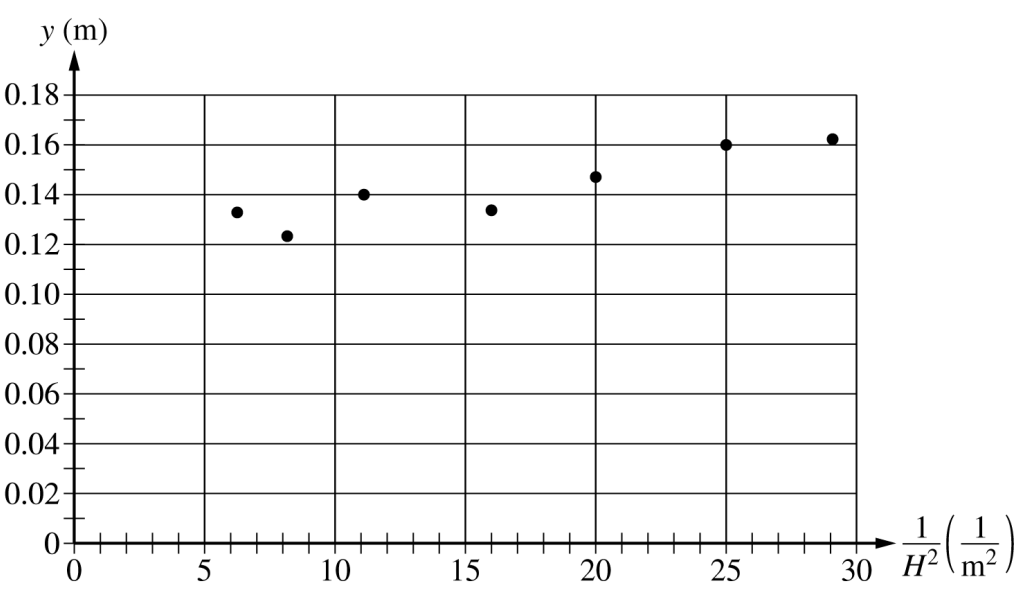


(b) Derive the relationship between y and H to show that $y = \frac{1}{4\pi\epsilon_0} \frac{Qq}{k_s H^2} + \frac{Mg}{k_s}$.

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Continue your response to **QUESTION 1** on this page.

(c) The students plot collected data of y as a function of $\frac{1}{H^2}$, as shown in the graph.



i. Draw the best-fit line for the data.
ii. Using the best-fit line, calculate an experimental value for the vacuum permittivity ϵ_0 when $Q = q = 2.00 \times 10^{-6} \text{ C}$ and $k_s = 25 \text{ N/m}$.

iii. Using the best-fit line, calculate an experimental value for the mass of Sphere B.

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Continue your response to **QUESTION 1** on this page.

(d) The students modify the experiment by replacing nonconducting Sphere B with conducting Sphere C that has the same charge $+Q$ and mass M . Sphere A is brought near Sphere C without touching, compressing the spring. Sphere C comes to rest.

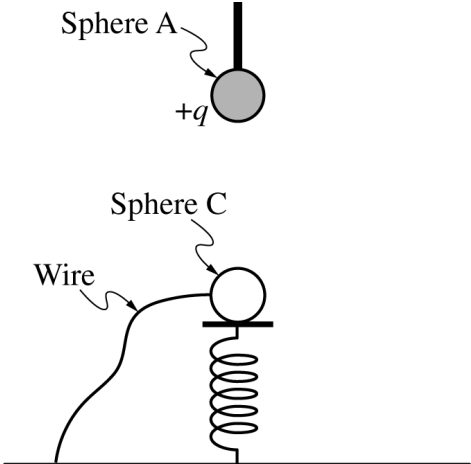
i. In the original experiment, when the centers of spheres A and B are a vertical distance H_1 apart, the spring is compressed a distance y_1 . In the modified experiment, when the centers of spheres A and C are a vertical distance H_1 apart, the spring is compressed a distance y_2 .

Is y_2 greater than, less than, or equal to y_1 ?

_____ $y_2 > y_1$ _____ $y_2 < y_1$ _____ $y_2 = y_1$

Justify your answer.

ii. Sphere C is then grounded with a wire. On the following figure, draw an arrow indicating the direction that the platform will move immediately after being grounded. If the platform remains stationary, write “does not move.”



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