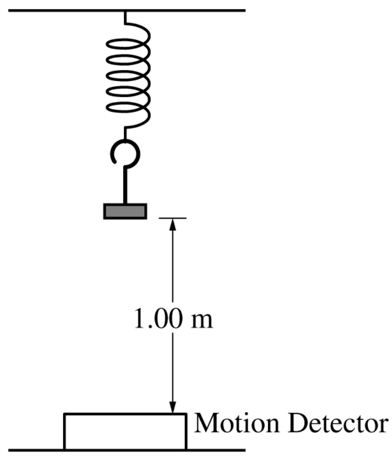
Begin your response to **QUESTION 5** on this page.



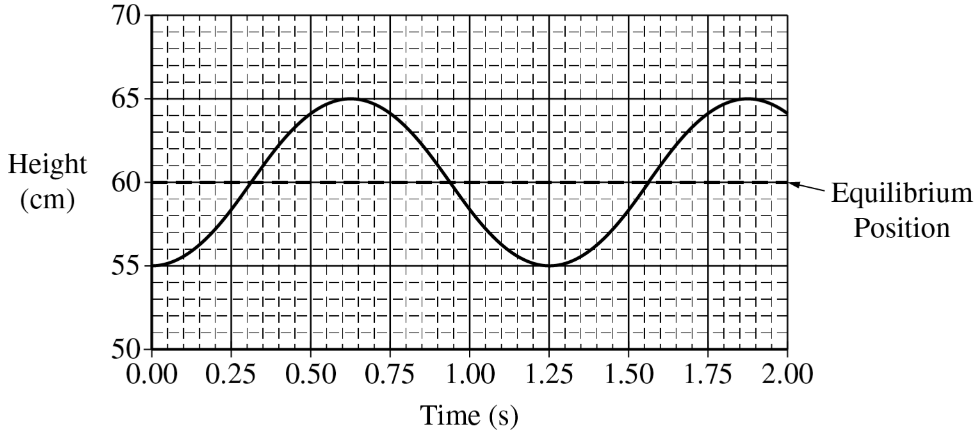
5. (7 points, suggested time 13 minutes)

A spring of unknown spring constant k_0 is attached to a ceiling. A lightweight hanger is attached to the lower end of the spring, and a motion detector is placed on the floor facing upward directly under the hanger, as shown in the figure above. The bottom of the hanger is 1.00 m above the motion detector.

A 0.50 kg object is placed on the hanger and allowed to come to rest at the equilibrium position. The spring is then stretched downward a distance d_0 from equilibrium and released at time $t = 0$. The motion detector records the height of the bottom of the hanger as a function of time. The output from the motion detector is shown in the graph on the following page.

GO ON TO THE NEXT PAGE.

Continue your response to **QUESTION 5** on this page.



(a) Using the information given and information taken from the graph, calculate the spring constant.

(b) At time 0.75 s, the object-spring-Earth system has a total kinetic energy K_0 and a total potential energy U_0. At 1.13 s, the object-spring-Earth system again has a total kinetic energy K_0 and a total potential energy U_0.

i. Explain how a feature of the graph indicates that the total kinetic energy of the system is the same at these two times.

ii. Briefly explain why the total potential energy of the system is the same at these two times.

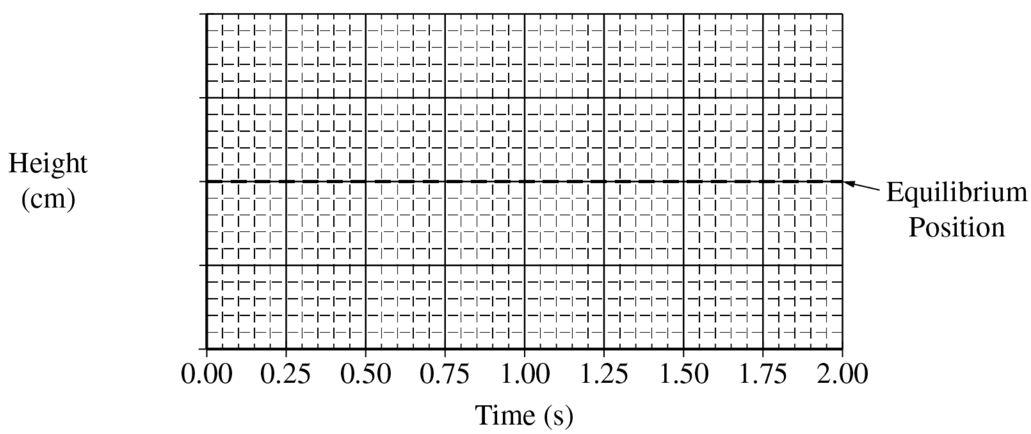
GO ON TO THE NEXT PAGE.

Continue your response to **QUESTION 5** on this page.

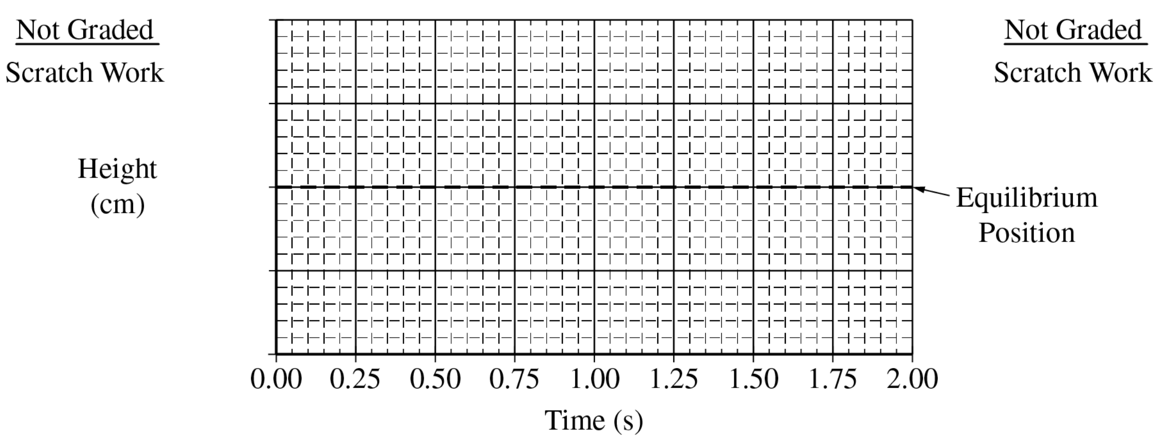
(c) The experiment is repeated with a spring of spring constant $4k_0$ and that has the same length as the original spring. The 0.50 kg object is hung from the new spring and allowed to come to rest at a new equilibrium position.

i. Determine the new equilibrium position above the motion detector.

ii. The object is again pulled down the same distance d_0 from the equilibrium position and released. On the following graph, draw a curve representing the motion of the object after it is released. Label the vertical axis with an appropriate numerical scale. A grid for scratch (practice) work is also provided.



The following graph is provided for scratch work only and will not be graded.



GO ON TO THE NEXT PAGE.

Question 5: Short Answer — 7 points

(a) For obtaining a period from the graph of 1.25 seconds — **1 point**

For substituting the values of period and mass into a valid equation for the spring constant — **1 point**

Example Response

$T = 1.25 \text{ s}$

$T = 2\pi\sqrt{\dfrac{m}{k}}$

$$k_0 = \frac{m}{\left(\dfrac{T}{2\pi}\right)^2} = \frac{0.50 \text{ kg}}{\left(\dfrac{1.25 \text{ s}}{2\pi}\right)^2} = 12.6 \text{ N/m}$$

Alternate Solution

For stating that the spring is stretched 0.40 m *to its equilibrium position (because the equilibrium height is* 60 cm *and the original height was* 100 cm*)* — 1 point

For substituting the amount of spring stretch and mass into a valid equation for the spring constant — 1 point

Alternate Example Response

The string is stretched 0.40 m *under a force of* $mg = 5$ N. *Because* $F = -kx$, *we have*

$$k = \frac{mg}{x} = \frac{5}{0.4} \text{ N/m} = 12.5 \text{ N/m}$$

Total for part (a) — 2 points

(b)(i) For a valid reason why the kinetic energy is the same at both times — **1 point**

Example Responses

The magnitude of the slope of the graph is the same at both times, this means the speed and, therefore, the kinetic energy is the same at both times.

OR

The object is the same distance from equilibrium at both times, so the kinetic energy must be the same.

(b)(ii) For a valid reason why the total potential energy is the same at both times — **1 point**

Example Responses

The total energy of the system is constant, so if K *is the same at both times,* U *must be also.*

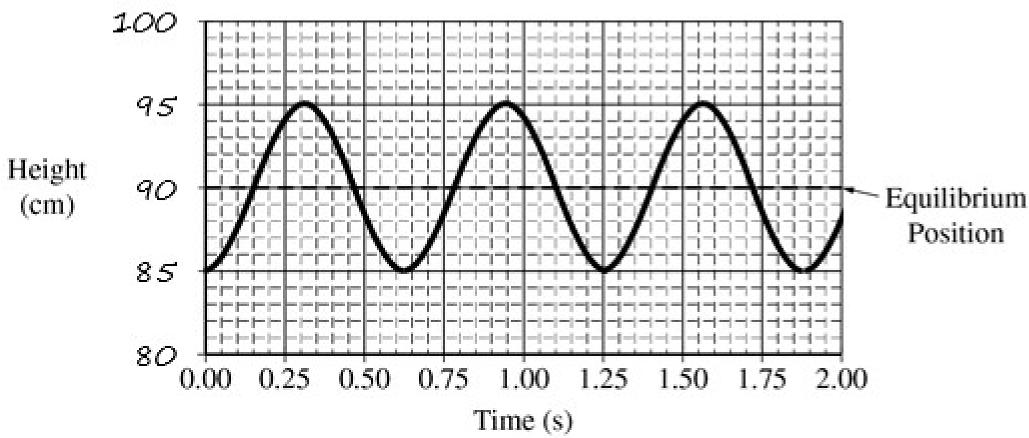
OR

The total energy of the system is constant, and equal energy is transferred from gravitational potential to spring potential.

Total for part (b) — 2 points

(c)(i)	For writing 90 cm or 0.90 m	**1 point**
(c)(ii)	For **both** of the following: • a graph that has the same amplitude as the original graph • a graph that is centered on the new equilibrium value consistent with (c)(i)	**1 point**
	For a graph with half the period as the original graph	**1 point**

Example Response



Total for part (c) 3 points

Total for question 5 7 points