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

PHYSICS 1

SECTION II

Time—1 hour and 30 minutes

5 Questions

Directions: Questions 1, 4, and 5 are short free-response questions that require about 13 minutes each to answer and are worth 7 points each. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.

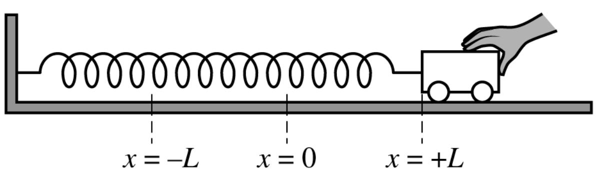


Figure 1

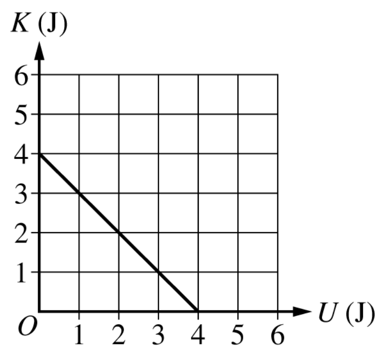


Figure 2

1. (7 points, suggested time 13 minutes)

A cart on a horizontal surface is attached to a spring. The other end of the spring is attached to a wall. The cart is initially held at rest, as shown in Figure 1. When the cart is released, the system consisting of the cart and spring oscillates between the positions $x = +L$ and $x = -L$. Figure 2 shows the kinetic energy of the cart-spring system as a function of the system's potential energy. Frictional forces are negligible.

(a) On the graph of kinetic energy K versus potential energy U shown in Figure 2, the values for the x-intercept and y-intercept are the same. Briefly explain why this is true, using physics principles.

GO ON TO THE NEXT PAGE.

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

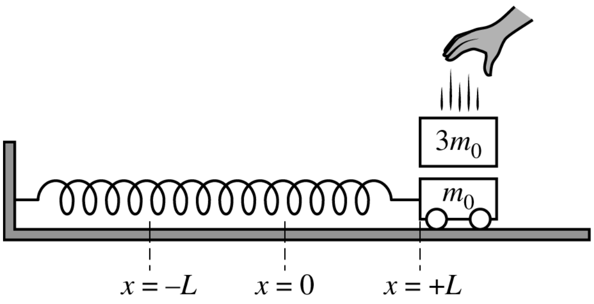


Figure 3

When the cart is at $+L$ and momentarily at rest, a block is dropped onto the cart, as shown in Figure 3. The block sticks to the cart, and the block-cart-spring system continues to oscillate between $-L$ and $+L$. The masses of the cart and the block are m_0 and $3m_0$, respectively.

(b) The frequency of oscillation before the block is dropped onto the cart is f_1. The frequency of oscillation after the block is dropped onto the cart is f_2. Calculate the numerical value of the ratio $\dfrac{f_2}{f_1}$.

GO ON TO THE NEXT PAGE.

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

(c) The dashed line in Figure 4 shows the kinetic energy K versus potential energy U of the block-cart-spring system after the block is dropped onto the cart. This graph is identical to the graph shown in Figure 2 for the cart-spring system before the block is dropped onto the cart.

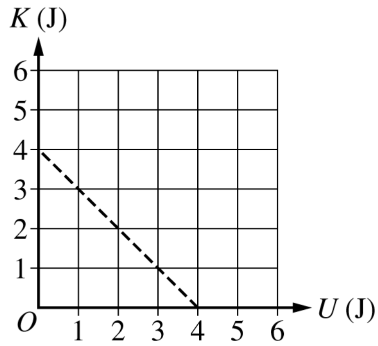


Figure 4

i. Briefly explain why the two graphs must be the same, using physics principles.

ii. After the block is dropped onto the cart, consider a system that consists only of the cart and the spring. On Figure 4, sketch a solid line that shows the kinetic energy of the system that consists of the cart and the spring but not the block after the block is dropped onto the cart.

GO ON TO THE NEXT PAGE.

Question 1: Short Answer — 7 points

(a) For an explanation that indicates that the maximum kinetic energy and maximum potential energy are the same due to energy conservation — **1 point**

Scoring Note: This point may be earned for only stating "conservation of energy."

Example Response

The maximum kinetic energy and maximum potential energy of the car-spring system are both 4 J, because energy is conserved in this system.

Total for part (a) — 1 point

(b) For using the equation for frequency or period in a ratio — **1 point**

Example Responses

$$\frac{\frac{1}{2\pi}\sqrt{\frac{k}{m_2}}}{\frac{1}{2\pi}\sqrt{\frac{k}{m_1}}} \quad \textbf{\textit{OR}} \quad \frac{\frac{1}{2\pi}\sqrt{\frac{k}{m_1}}}{\frac{1}{2\pi}\sqrt{\frac{k}{m_2}}} \quad \textbf{\textit{OR}} \quad \frac{2\pi\sqrt{\frac{m_2}{k}}}{2\pi\sqrt{\frac{m_1}{k}}} \quad \textbf{\textit{OR}} \quad \frac{2\pi\sqrt{\frac{m_1}{k}}}{2\pi\sqrt{\frac{m_2}{k}}}$$

Scoring Note: Simplified versions of the above ratios also earn this point.

For substituting the total mass $4m_0$ into the correct ratio: $\frac{f_2}{f_1}$ or $\frac{T_1}{T_2}$ — **1 point**

Example Response

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

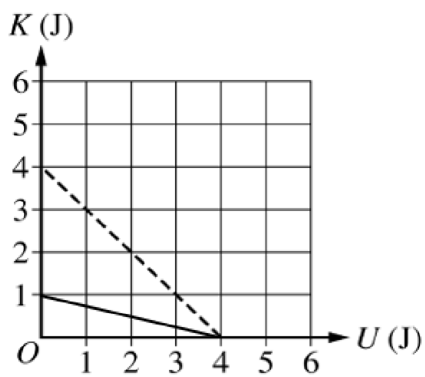
$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

$$\frac{f_2}{f_1} = \frac{\frac{1}{2\pi}\sqrt{\frac{k}{4m_0}}}{\frac{1}{2\pi}\sqrt{\frac{k}{m_0}}}$$

$$\frac{f_2}{f_1} = \frac{1}{2}$$

Total for part (b) — 2 points

(c)(i)	For a valid explanation in terms of work or energy for why the systems' energies should be the same Accept **one** of the following: • No work is done on the system • The maximum spring potential energy is the same • The force exerted on the system is perpendicular to the direction of motion	**1 point**
	Example Response *The maximum potential energy of the system does not depend upon the mass of the system, therefore there will be no change when the block is added.*	
(c)(ii)	For drawing a single straight line with a horizontal intercept that is the same as the horizontal intercept of the original graph of 4 J	**1 point**
	For drawing a line with a vertical intercept that is less than the vertical intercept in the original graph	**1 point**
	For drawing a line with the correct vertical intercept of 1 J	**1 point**
	Example Response	



Total for part (c) **4 points**

Total for question 1 **7 points**