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

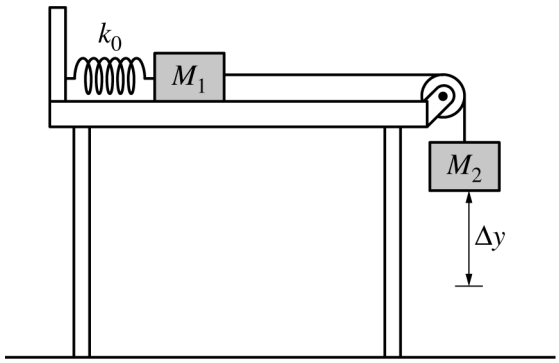
PHYSICS 1

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.



1. (7 points, suggested time 13 minutes)

Two blocks are connected by a string that passes over a pulley, as shown above. Block 1 is on a horizontal surface and is attached to a spring that is at its unstretched length. Frictional forces are negligible in the pulley's axle and between the block and the surface. Block 2 is released from rest and moves downward before momentarily coming to rest.

k_0 is the spring constant of the spring.
M_1 is the mass of block 1.
M_2 is the mass of block 2.
Δy is the distance block 2 moves before momentarily coming to rest.

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

(a)

i. Block 2 starts from rest and speeds up, then it slows down and momentarily comes to rest at a position below its initial position. In terms of only the forces directly exerted on block 2, explain why block 2 initially speeds up and explain why it slows down to a momentary stop.

ii. Derive an expression for the distance Δy that block 2 travels before momentarily coming to rest. Express your answer in terms of k_0, M_1, M_2, and physical constants, as appropriate.

(b) Indicate whether the total mechanical energy of the blocks-spring-Earth system changes as block 2 moves downward.

___ Changes ___ Does not change

Briefly explain your reasoning.

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

Consider the system that includes the spring, Earth, both blocks, and the string, but not the surface. Let the initial state be when the blocks are at rest just before they start moving, and let the final state be when the blocks first come momentarily to rest. Diagram A at left below is a bar chart that represents the energies in the scenario where there is negligible friction between block 1 and the surface.

The shaded-in bars in the energy bar charts represent the potential energy of the spring and the gravitational potential energy of the blocks-Earth system, U_s and U_g, respectively, in the initial and final states. Positive energy values are above the zero-point line ("0") and negative energy values are below the zero-point line.

Diagram A: Negligible Friction

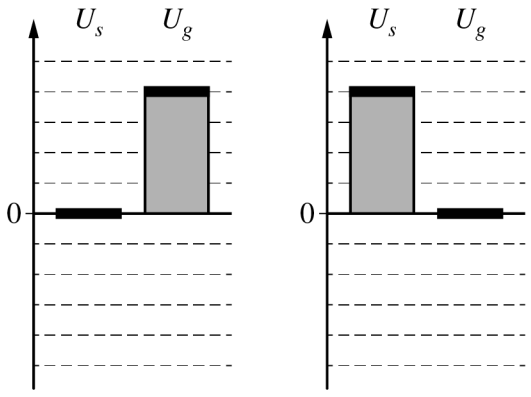
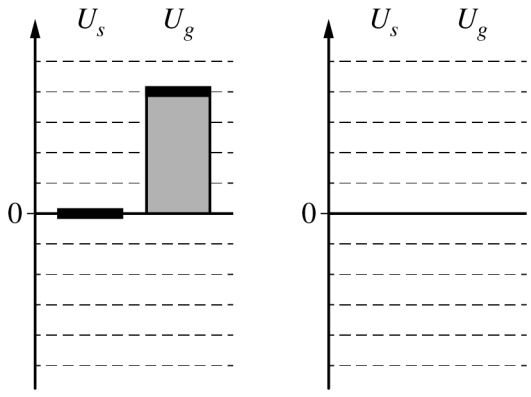


Diagram B: Nonnegligible Friction



(c) Complete diagram B (at right above) for the scenario in which friction is nonnegligible. The energies for the initial state are already provided. Shade in the energies in the final state using the same scale as in diagram A.

- Shaded regions should start at the solid line representing the zero-point line.
- Represent any energy that is equal to zero with a distinct line on the zero-point line.

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Question 1: Short Answer — 7 points

(a)(i) For relating the net force to acceleration or change in velocity — **1 point**

For a correct description of the relative magnitudes of the tension and gravitational forces during Block 2's motion — for both $T > W$ and $T < W$ — **1 point**

Scoring Notes: This point is not earned if the spring force is explicitly stated to be a force directly exerted on Block 2. If the spring force is mentioned, it must be connected to the string tension.

Example Response

The direction of the acceleration and the direction of the net force are the same. The block speeds up when the gravitational force is greater than the tension and then slows down because the tension becomes larger than the gravitational force.

(a)(ii) For an equation of conservation of energy that includes a gravitational potential energy term and a spring potential energy term — **1 point**

For a correct expression for Δy that depends only on M_2, k_0, and g — **1 point**

$$\Delta y = \frac{2M_2 g}{k_0}$$

Example Response

$U_i = U_f \quad (K_i = K_f = 0)$

$U_{g\text{-}M_1} + M_2 g \Delta y = U_{g\text{-}M_1} + \frac{1}{2} k_0 \Delta y^2$

$M_2 g \Delta y = \frac{1}{2} k_0 \Delta y^2$

$M_2 g = \frac{1}{2} k_0 \Delta y$

$\Delta y = \frac{2M_2 g}{k_0}$

Total for part (a) 4 points

(b) For selecting "Does not change" with a correct explanation — **1 point**

Example Response

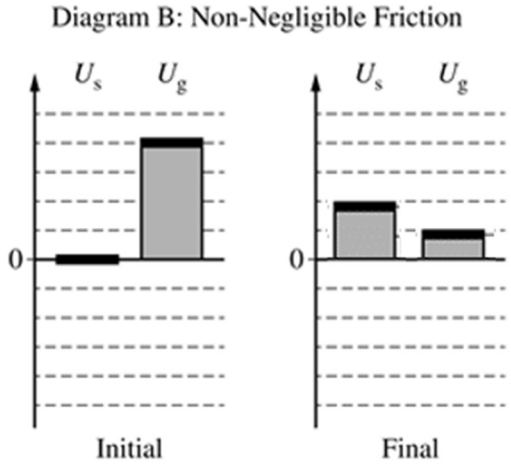
There are no external forces on the system and no energy is dissipated by friction, so the total mechanical energy stays the same.

Total for part (b) 1 point

(c) For a final bar chart where both U_s and U_g are positive **1 point**

For a final bar chart where the sum of U_s and U_g is less than four units **1 point**

Example Response



Total for part (c) 2 points

Total for question 1 7 points