2022

AP CollegeBoard

AP® Physics 1: Algebra-Based

Sample Student Responses and Scoring Commentary

Inside:

Free-Response Question 1

- ☑ **Scoring Guidelines**
- ☑ **Student Samples**
- ☑ **Scoring Commentary**

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

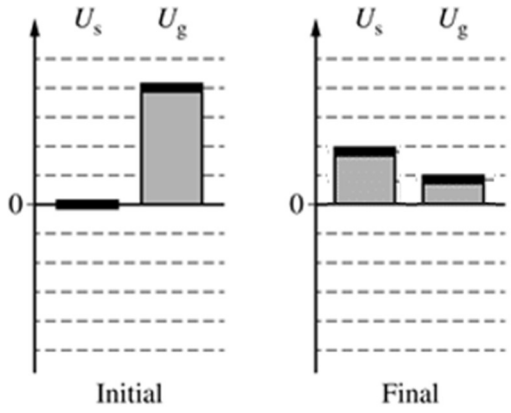
There are no external forces on the system and no energy is dissipated by friction, so the total mechanical energy stays the same.

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

Diagram B: Non-Negligible Friction



Total for part (c) 2 points

Total for question 1 7 points

Question 1

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

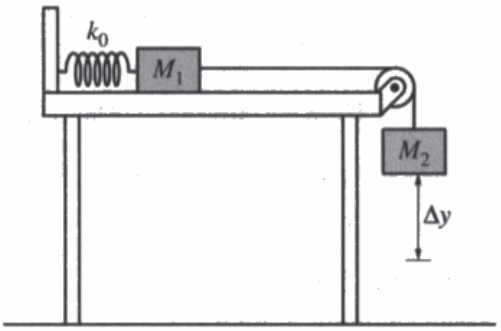
PHYSICS 1

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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Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 1

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.

Block 2 initially speeds up because the force of gravity is greater than the tension. It slows to a momentary stop some time after tension exceeds gravity which causes it to accelerate in the opposite direction as its velocity.

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.

conservation of energy: $M_2 g \Delta y = \frac{1}{2} k_0 (\Delta y)^2$

(note no terms for kinetic energy because start and end velocity = 0)

($M_2 g \Delta y$: initial potential energy)

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

(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.

The blocks-spring-Earth system is a closed system and there is no net external forces on this system.

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Question 1

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

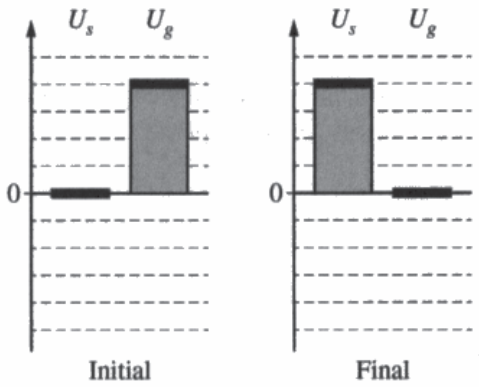
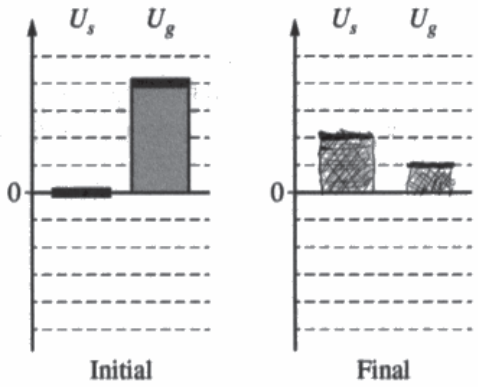


Diagram B: Nonnegligible Friction



(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

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SECTION II

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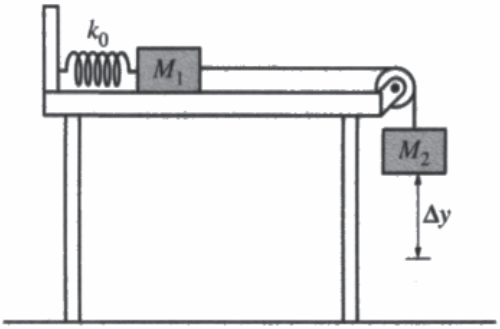

1. (7 points, suggested time 13 minutes)

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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Question 1

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.

it initially only experiences gravity, but as it descends, the tension of the rope begins to be greater than the force of gravity on the block, causing it to slow to a 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.

$\Sigma F = M \cdot a$ $\quad F_{g(m_2)} = m_2 g$

$\Sigma F = M_2 g - F_T$

$E_i = E_f$

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

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

$2 M_2 g = k_0 \Delta y$

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

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

___ Changes $\quad$ X Does not change

Briefly explain your reasoning.

No chemical energy is converted into mechanical energy, and friction is negligible. all of the U_g that is lost as M_2 descends is converted into KE and U_s, then completely into U_s as M_2 comes to rest. during this process no energy is added to or lost from the system

Question 1

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

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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

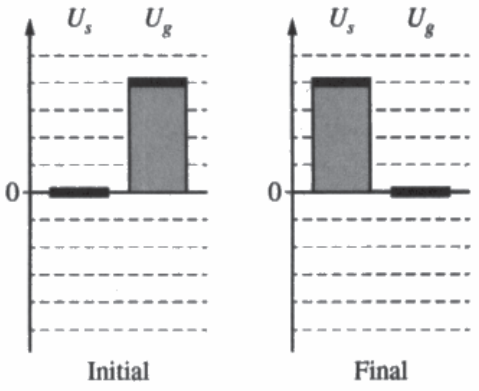
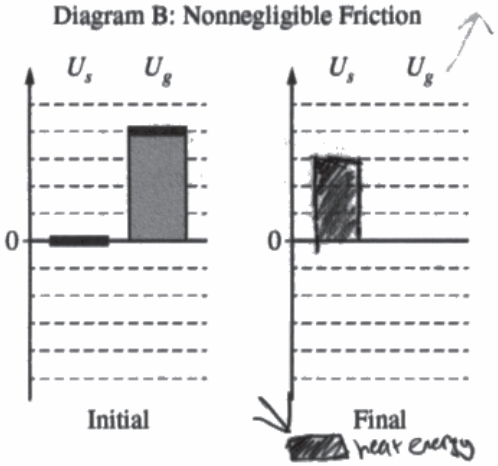


Diagram B: Nonnegligible Friction



(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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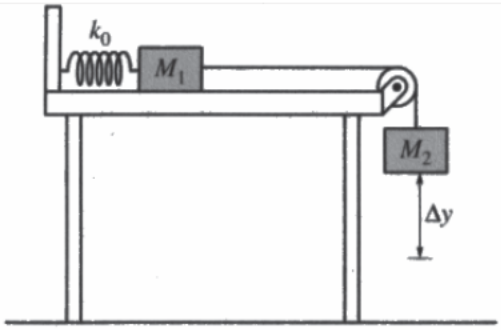

1. (7 points, suggested time 13 minutes)

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Question 1

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(a) ~~To whoever~~

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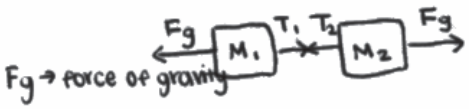
Block 2 initially speeds up because the force of gravity is greater than the force of tension at this moment in time, thus resulting in an increase in velocity. Then, block 2 slows down to a momentary stop as the force of gravity is now equal to the force of tension, they are ~~an~~ equal and opposite forces.

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.

$F = F_N \mu$

$F = mg k_0$



$F_g \rightarrow$ force of gravity

$F_T \rightarrow$ tension force

$-F_g + T_1 - T_2 + F_g = \Sigma F$

$-mg + T_1 - T_2 + mg = (\frac{m_1}{m_1 + m_2})\, a$

$T_1 - T_2 = mg k_0$

$a = \frac{T_1 - T_2}{m_1 + m_2}$

$a = \frac{2F_T}{m_1 + m_2}$

$\Delta y = v_0 t + \frac{1}{2} a t^2$

$\Delta y = (0)(t) + (\frac{1}{2})(a)(t^2)$

$\Delta y = \frac{1}{2} a t^2$

$\Delta y = (\frac{1}{2})(\frac{2F_T}{m_1 + m_2})(t^2)$

$\Delta y = \frac{(mg k_0)}{m} t^2$

$\Delta y = g k_0 t^2$

$\Delta y = \frac{F_T t^2}{m_1 + m_2}$

$\Delta y = \frac{mg k_0 t^2}{m_1 + m_2}$

(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.

Due to the law of Conservation of Energy, or in a closed system, energy cannot be created nor destroyed. Although the potential and kinetic energy may change, the total mechanical energy will remain constant.

Question 1

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

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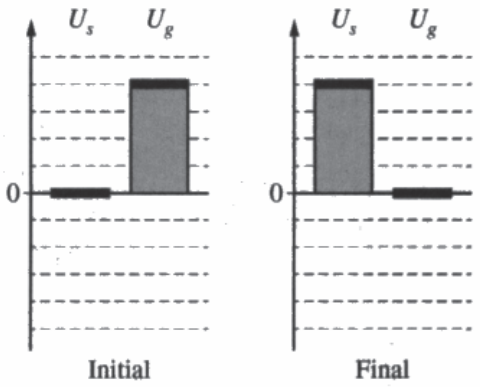
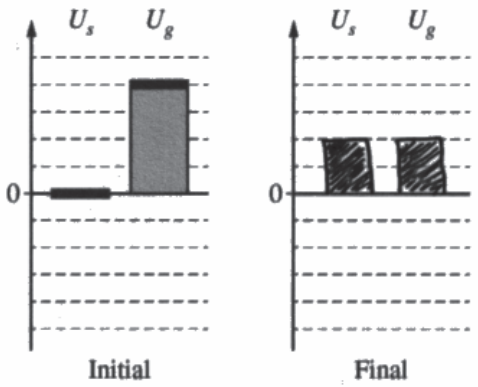


Diagram B: Nonnegligible Friction



(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.

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- Represent any energy that is equal to zero with a distinct line on the zero-point line.

GO ON TO THE NEXT PAGE.

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Question 1

Note: Student samples are quoted verbatim and may contain spelling and grammatical errors.

Overview

The responses were expected to demonstrate the ability to:

- Identify forces exerted on an object and relate the net force to the acceleration of the object.
- Describe energy transformations as a system moves to and from rest.
- Derive an equation for the displacement of a block attached to a spring using energy conservation.
- Communicate knowledge of forces and energy transformations through verbal, mathematical, and graphical forms.
- Represent energy changes using energy bar charts in a system with and without friction present.

Sample: 1A
Score: 7

Part (a)(i) earned 2 points. The first point was earned for indicating that Block 2 speeds up due to the force of gravity being greater than the tension. Even though the term "net force" is not explicitly used, reference to the force of gravity and the force of tension on Block 2 are accepted as describing the "net force." The second point was earned for stating that "tension exceeds gravity" and this causes Block 2 to change direction. Part (a)(ii) earned 2 points. The first point was earned for providing a conservation of energy equation with the gravitational and spring potential energies. The second point was earned for a correct expression of Δy using the correct terms. Part (b) earned 1 point for a correct checking of "Does not change." The response identifies there are no net external forces on the system. Part (c) earned 2 points. The first point was earned for representing both bars as positive. The second point was earned for the sum of the two energies being less than four units.

Sample: 1B
Score: 4

Part (a)(i) earned 1 point. The first point was earned because the response mentions the net force on Block 2 and relates the net force to the acceleration or change in velocity: "force of tension of the rope begins to be greater than the force of gravity on the block, causing it to slow to a stop." The second point was not earned. The response states the tension begins to be greater than the force of gravity causing it to slow to a stop. However, there is no mention of the gravitational force being greater than the tension force to get Block 2 to move. Part (a)(ii) earned 2 points. The first point was earned because the response shows the conservation of energy and includes both the gravitational and spring potential energies. The second point was earned because the response has the correct expression written for Δy based on the given terms. Part (b) earned 1 point for a correct checking of "Does not change," and the response states that friction is negligible. Part (c) earned 0 points. The first point was not earned because the response does not correctly draw both energy bars as positive values. The second point was not earned because the response does not draw an energy bar for the gravitational energy and the sum of the energies is not less than four units.

Question 1 (continued)

Sample: 1C
Score: 2

Part (a)(i) earned 1 point. The first point was earned because the response indicates that the increase of velocity of Block 2 is due to the force of gravity being greater than the force of tension. Even though the term "net force" is not explicitly used, reference to the force of gravity and the force of tension on Block 2 are accepted as describing the "net force." The second point was not earned because the response does not mention $T > W$ for the motion of Block 2. Part (a)(ii) earned 0 points. The first point was not earned because the response does not apply conservation of energy with gravitational and spring potential energies. The second point was not earned because the response does not solve for the correct expression of Δy using the given terms. Part (b) earned 0 points, because the response does not mention no external forces or no friction acting on the system. Part (c) earned 1 point. The first point was earned because the response has both energy bars in the positive region. The second point was not earned because the response does not show the sum of the energy bars as less than four units.