

Question 2: Paragraph Argument Short Answer

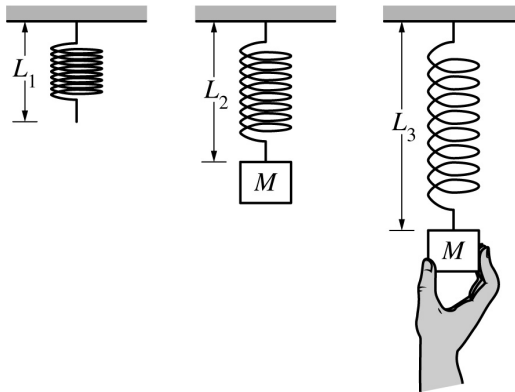


Figure 1

Figure 2

Figure 3

2. A spring with unstretched length L_1 is hung vertically, with the top end fixed in place, as shown in Figure 1 above. A block of mass M is attached to the bottom of the spring, as shown in Figure 2, and the spring has length $L_2 > L_1$ when the block hangs at rest. The block is then pulled downward and held in place so that the spring is stretched to a length $L_3 > L_2$, as shown in Figure 3.
- (A) On the dot below, which represents the block in Figure 3, draw and label the forces (not components) exerted on the block. Each force must be represented by a distinct arrow starting on, and pointing away from, the dot.



- (B) The student releases the block. Consider the time during which the block is moving upward toward its equilibrium position and the spring length is still longer than L_2 .

In a clear, coherent paragraph-length response that may also contain diagrams and/or equations, indicate why the total mechanical energy is increasing, decreasing, or constant for each of the systems listed below.

- System 1: The block
- System 2: The block and the spring
- System 3: The block, the spring, and Earth

Use E_1 , E_2 , and E_3 to denote the total mechanical energy of systems 1, 2, and 3, respectively.

Scoring Guidelines for Question 2: Paragraph Argument Short Answer 7 points

Learning Objectives: 3.B.2.1 3.E.1.2 4.C.1.1 5.A.2.1 5.B.4.1 5.B.4.2

(A) Draw and label the forces (not components) exerted on the block.

1 point

Accept the following:



1.1

One point for including all three labelled forces exerted on the block:

- the upward spring force,
- the downward gravitational force,
- and the downward force of the hand holding the block.

One point for including at least one of the three forces exerted on the block, with no extraneous forces.

1 point

1.1

Total for part (A)

2 points

(B) In a clear, coherent paragraph-length response that may also contain diagrams and/or equations, indicate why the total mechanical energy is increasing, decreasing, or constant for each of the systems listed below.

1 point

6.4

- System 1: The block
- System 2: The block and the spring
- System 3: The block, the spring, and Earth

One point for a response with no incorrect claims about which forms of energy are present in each system.

- Note: Responses that do not explicitly refer to the forms of energy in one or more of the systems can still earn this point.

The correct forms of energy in each system are the following:

- System 1: Kinetic energy K_{block} of the block (There is no potential energy for system 1.)
- System 2: K_{block} and the potential energy U_{spring} of the spring
- System 3: K_{block} , U_{spring} , and the gravitational potential energy U_{grav} of the block-Earth system

One point for correctly providing an indication that total mechanical energy is increasing for the block.

1 point

1.4

Examples of acceptable statements:

- The block is accelerating upward with increasing speed.
- The net force on the block is upward, in the direction of the block's velocity, so the block's kinetic energy is increasing.

One point for correct statement of why the total mechanical energy is decreasing for the block-spring system.

1 point

2.1

Examples of acceptable reasoning statements:

- The only external forces exerted on the block-spring system (system 2) are the gravitational force on the block and the force holding the top end of the spring in place. The gravitational force is in the opposite direction of the block's motion and so does negative work on system 2. The point of application of the force on the top end of the spring does not move, so this force does zero work on the system. Overall, negative work is being done on system 2, so E_2 must be decreasing.

- System 2 has total mechanical energy:

$$E_2 = K_{\text{block}} + U_{\text{spring}}, \text{ which equals } E_3 - U_{\text{grav}}.$$

E_3 is the total mechanical energy of System 3. E_3 is constant, while U_{grav} is increasing because the block is moving upward. So $E_2 = E_3 - U_{\text{grav}}$ must be decreasing.

One point for correct statement that the total mechanical energy is constant for a closed system such as the block-spring-Earth system.

1 point

6.4

Examples of acceptable claim statements:

- System 3 is closed, so its total mechanical energy remains constant.
- No external forces act on system 3, so its total mechanical energy remains constant.

Note: It is not necessary to state that energy is neither dissipated or added by converting other forms of energy into mechanical energy, since there is no mention of potential causes for these processes (e.g., friction to dissipate mechanical energy, or an explosion to add mechanical energy).

One point for a logical, relevant, and internally consistent argument that addresses the required argument, explanation or question asked.

1 point

1.4

Example of an acceptable response:

- For system 1 of just the block: When the force holding the block is removed, the block's acceleration and the net force on the block are upward since the spring force is greater than the gravitational force. The net force is in the direction of the block's motion, so its speed and kinetic energy are both increasing. The total mechanical energy is the kinetic energy for a single-object system, so E_1 is increasing.

System 3 can be considered a closed system with no external forces exerted on it, so E_3 is constant.

Note that:

$$E_3 = K_{\text{block}} + U_{\text{spring}} + U_{\text{grav}}$$

where K_{block} is the block's kinetic energy, U_{spring} is the spring's potential energy, and U_{grav} is the gravitational potential energy of the block-Earth system.

System 2 has total mechanical energy:

$$E_2 = K_{\text{block}} + U_{\text{spring}}, \text{ which equals } E_3 - U_{\text{grav}}.$$

E_3 is constant, while U_{grav} is increasing because the block is moving upward. So $E_2 = E_3 - U_{\text{grav}}$ must be decreasing.

Total for part (B)

5 points

Total for question 2

7 points