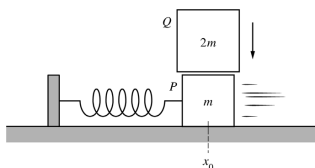


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Question 5

7 points total

**Distribution
of points**



Block P of mass m is on a horizontal, frictionless surface and is attached to a spring with spring constant k . The block is oscillating with period T_P and amplitude A_P about the spring's equilibrium position x_0 . A second block Q of mass $2m$ is then dropped from rest and lands on block P at the instant it passes through the equilibrium position, as shown above. Block Q immediately sticks to the top of block P , and the two-block system oscillates with period T_{PQ} and amplitude A_{PQ} .

- (a) LO / SP: 3.B.3.1 / 6.4
1 point

Determine the numerical value of the ratio T_{PQ}/T_P .

For a correct answer: $\sqrt{3}$

1 point

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Question 5 (continued)

**Distribution
of points**

- (b) LO / SP: 3.B.3.1 / 6.4, 7.2; 3.B.3.4 / 2.2, 6.2; 4.C.1.1 / 1.4, 2.2; 4.C.1.2 / 6.4;
 5.B.3.1 / 2.2, 6.4; 5.B.3.3 / 1.4, 2.2; 5.B.4.1 / 6.4, 7.2; 5.B.4.2 / 1.4, 2.1, 2.2; 5.D.2.1 / 6.4, 7.2
 6 points

How does the amplitude of oscillation A_{PQ} of the two-block system compare with the original amplitude A_P of block P alone?

_____ $A_{PQ} < A_P$ _____ $A_{PQ} = A_P$ _____ $A_{PQ} > A_P$

In a clear, coherent paragraph-length response that may also contain diagrams and/or equations, explain your reasoning.

Correct answer: $A_{PQ} < A_P$.		
<u>Note:</u> The response is graded even if an incorrect selection is made.		
For applying conservation of momentum to the collision		1 point
For correctly finding that the post-collision speed has decreased (or, for determining that $v_f = \frac{1}{3}v_i$)		1 point
<u>Note:</u> The first 2 points can be earned for stating that the collision is inelastic		
For stating or implying that the system's kinetic energy has decreased (or, for calculating a lower final kinetic energy)		1 point
For stating or implying kinetic energy of blocks right after collision equals maximum potential energy of spring OR For stating or implying that the maximum potential energy equals the total mechanical energy just after the collision (Simply stating that $E_{\text{tot}} = \frac{1}{2}kA^2$ is sufficient.)		1 point
For stating or implying that maximum potential energy is reached when the displacement from equilibrium equals the amplitude of oscillation		1 point
<u>Note:</u> The previous 2 points can be earned in a single sentence in which one or both of the points is implicit.		
For a logical, relevant, and internally consistent argument that addresses the required argument or question asked and follows the guidelines described in the published requirements for the paragraph-length response		1 point

<u>Alternate solution for first 2 points in part (b):</u> A frictional force is exerted on block P by Q , so it slows down.		
<u>Note:</u> The third point can be earned if energy loss is stated.		2 points

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Question 5 (continued)

Example:

The second block (*Q*) adds mass without changing the horizontal momentum of the two-block system. In effect, block *P* (mass *m*) becomes block *PQ* (mass *3m*). This reduces the speed at equilibrium from $v_{\max}$ to $v_{\max}/3$ according to conservation of momentum. To see how this affects amplitude, we must analyze what happens to the maximum kinetic energy (*K*) of the oscillating mass:

$$K_P = \frac{1}{2}mv_{\max}^2 \qquad K_{PQ} = \frac{1}{2}(3m)\left(\frac{v_{\max}}{3}\right)^2 = \frac{1}{6}mv_{\max}^2 = \frac{1}{3}K_P$$

Because the maximum *K* is reduced, this means the maximum potential energy in the spring is also reduced (to 1/3 of its former value). Because amplitude is related

to maximum potential energy $\left(U_{\max} = \frac{1}{2}kA^2\right)$, the amplitude of block *PQ* is less than that of block *P*.

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Question 5 (continued)

Learning Objectives (LO)

LO 3.B.3.1: The student is able to predict which properties determine the motion of a simple harmonic oscillator and what the dependence of the motion is on those properties. [See Science Practices 6.4, 7.2]

LO 3.B.3.4: The student is able to construct a qualitative and/or a quantitative explanation of oscillatory behavior given evidence of a restoring force. [See Science Practices 2.2, 6.2]

LO 4.C.1.1: The student is able to calculate the total energy of a system and justify the mathematical routines used in the calculation of component types of energy within the system whose sum is the total energy. [See Science Practices 1.4, 2.1, 2.2]

LO 4.C.1.2: The student is able to predict changes in the total energy of a system due to changes in position and speed of objects or frictional interactions within the system. [See Science Practice 6.4]

LO 5.B.3.1: The student is able to describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy. [See Science Practices 2.2, 6.4, 7.2]

LO 5.B.3.3: The student is able to apply mathematical reasoning to create a description of the internal potential energy of a system from a description or diagram of the objects and interactions in that system. [See Science Practices 1.4, 2.2]

LO 5.B.4.1: The student is able to describe and make predictions about the internal energy of systems. [See Science Practices 6.4, 7.2]

LO 5.B.4.2: The student is able to calculate changes in kinetic energy and potential energy of a system, using information from representations of that system. [See Science Practices 1.4, 2.1, 2.2]

LO 5.D.2.1: The student is able to qualitatively predict, in terms of linear momentum and kinetic energy, how the outcome of a collision between two objects changes depending on whether the collision is elastic or inelastic. [See Science Practices 6.4, 7.2]