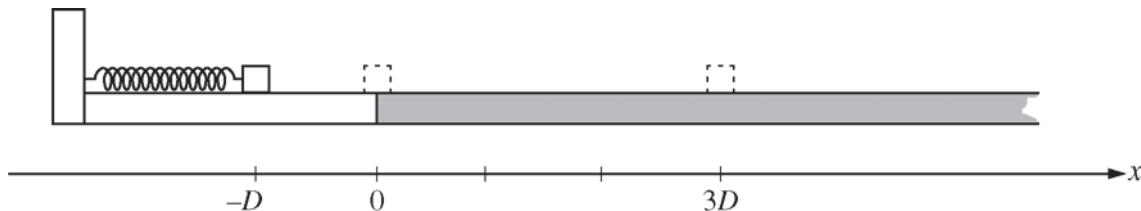


2015 AP® PHYSICS 1 FREE-RESPONSE QUESTIONS

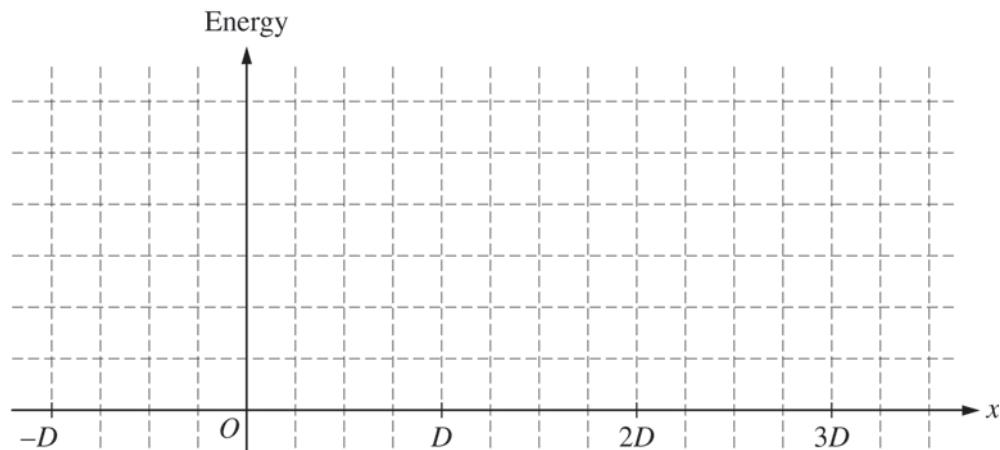


3. (12 points, suggested time 25 minutes)

A block is initially at position $x = 0$ and in contact with an uncompressed spring of negligible mass. The block is pushed back along a frictionless surface from position $x = 0$ to $x = -D$, as shown above, compressing the spring by an amount $\Delta x = D$. The block is then released. At $x = 0$ the block enters a rough part of the track and eventually comes to rest at position $x = 3D$. The coefficient of kinetic friction between the block and the rough track is μ .

- (a) On the axes below, sketch and label graphs of the following two quantities as a function of the position of the block between $x = -D$ and $x = 3D$. You do not need to calculate values for the vertical axis, but the same vertical scale should be used for both quantities.

- The kinetic energy K of the block
- The potential energy U of the block-spring system



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The spring is now compressed twice as much, to $\Delta x = 2D$. A student is asked to predict whether the final position of the block will be twice as far at $x = 6D$. The student reasons that since the spring will be compressed twice as much as before, the block will have more energy when it leaves the spring, so it will slide farther along the track before stopping at position $x = 6D$.

- (b)
- i. Which aspects of the student’s reasoning, if any, are correct? Explain how you arrived at your answer.
 - ii. Which aspects of the student’s reasoning, if any, are incorrect? Explain how you arrived at your answer.
- (c) Use quantitative reasoning, including equations as needed, to develop an expression for the new final position of the block. Express your answer in terms of D .
- (d) Explain how any correct aspects of the student’s reasoning identified in part (b) are expressed by your mathematical relationships in part (c). Explain how your relationships in part (c) correct any incorrect aspects of the student’s reasoning identified in part (b). Refer to the relationships you wrote in part (c), not just the final answer you obtained by manipulating those relationships.

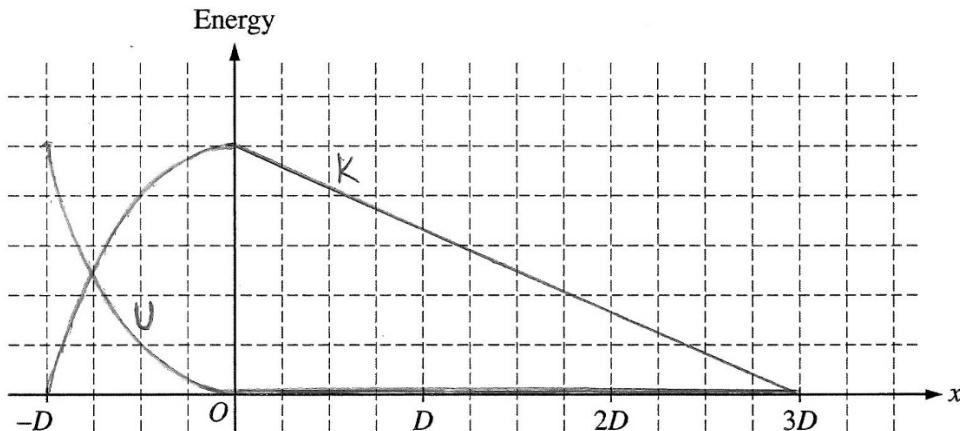
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Question 3

12 points total

(a) 4 points

**Distribution
of points**



For sketching either energy curve with a reasonably correct shape between $x = -D$ and $x = 0$, with zero and maximum values at the correct locations

1 point

For sketching two curves from $x = -D$ to $x = 0$ with shapes and values such that the total energy is constant (even if the curves are incorrect)

1 point

For sketching potential energy equal to zero from $x = 0$ to $x = 3D$

1 point

For sketching kinetic energy as a linear function from its maximum value at $x = 0$ to zero at $x = 3D$

1 point

(b)

(i) 1 point

For identifying that the student is correct that the block will have more energy when it leaves the spring

1 point

(ii) 1 point

For identifying that the student is incorrect about the new final position of the block because the spring's energy does not scale linearly with its compression

1 point

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Question 3 (continued)

**Distribution
of points**

(c) 3 points

For indicating that the final energy in the spring (which becomes the mechanical energy of the block as it reaches the rough track) is four times the original energy in the spring

1 point

For indicating that the frictional force remains the same

1 point

For equating the initial energy in the spring to an expression that shows that the energy dissipated by friction is proportional to the distance the block slides down the rough track

1 point

Example:

$$U_1 = \frac{1}{2}kD^2 \text{ and } U_2 = \frac{1}{2}k(2D)^2 \text{ so } U_2 = 4U_1$$

$$W_1 = \mu mg(3D) \text{ and } W_2 = \mu mg\Delta x_2$$

$$W_1 = U_1 \text{ and } W_2 = U_2 = 4U_1 = 4W_1$$

$$\mu mg\Delta x_2 = 4(\mu mg(3D))$$

$$\Delta x_2 = 4(3D) = 12D$$

(d) 3 points

For indicating that the student's correct reasoning that the block has more energy in the second situation is expressed by the calculations comparing the initial energy in the spring

1 point

For indicating that the student's correct reasoning that the block will slide farther is expressed by an equation that indicates that the work done by friction to stop the block in the second situation is some factor greater than the work done in the first situation

1 point

For indicating that the student's incorrect reasoning that energy scales linearly with the spring's compression is corrected by the expression for the initial energy of the spring

1 point