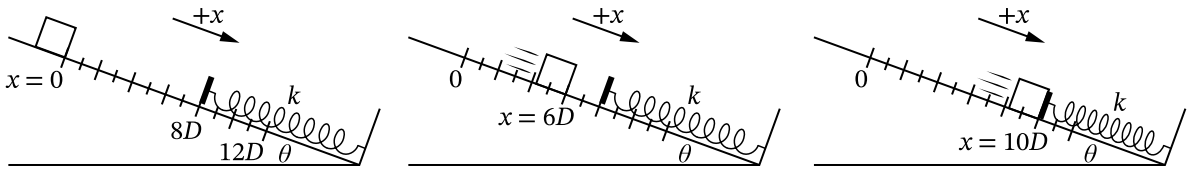
Question 2: Version J

2. A block of mass M is released from rest at position $x = 0$ near the top of a ramp. The ramp makes an angle of θ with the horizontal. The block slides down the ramp with negligible friction. At $x = 8D$ the block makes contact with an uncompressed spring with spring constant k. The spring is then compressed and the block momentarily comes to rest at $x = 12D$. Figure 1 shows the instants when the block is at $x = 0$, $x = 6D$, and $x = 10D$, respectively.



A. Figure 4 shows an energy bar chart that represents the kinetic energy K of the block, the gravitational potential energy U_g of the block-spring-Earth system, and the spring potential energy U_s of the block-spring-Earth system at the instant that the block is at $x = 10D$. The gravitational potential energy U_g of the block-spring-Earth system is defined to be zero when the block momentarily comes to rest at $x = 12D$.

Draw shaded bars that represent K, U_g, and U_s to complete the energy bar charts in Figure 2 and Figure 3 for when the block is released from rest at $x = 0$ and for when the block is at $x = 6D$, respectively.

- Shaded bars should start at the dashed line that represents zero energy.
- Represent any energy that is equal to zero with a distinct line on the zero-energy line.
- The relative heights of each shaded bar should reflect the magnitude of the respective energy consistent with the scale used in Figure 4.

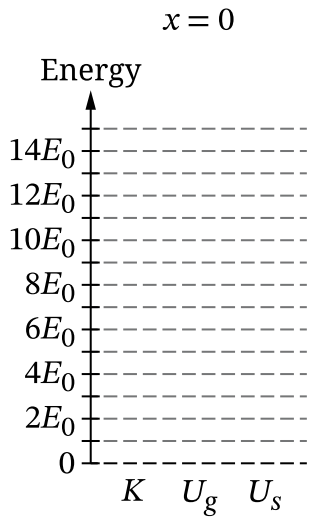


Figure 2

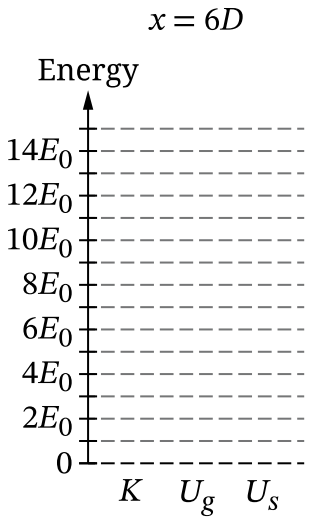


Figure 3

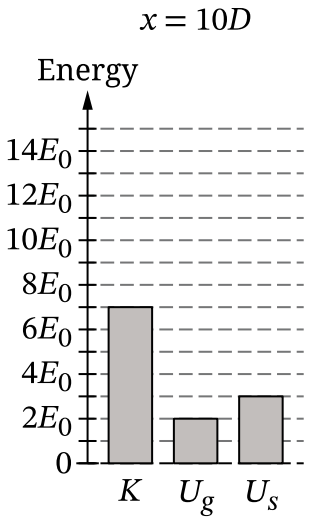
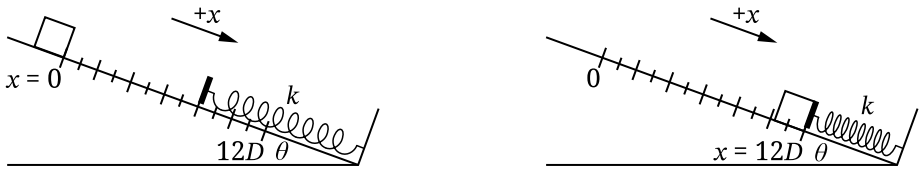


Figure 4

B. Figure 5 shows the block at $x = 0$ when the block is released from rest and the block at $x = 12D$ when the block momentarily comes to rest against the compressed spring.

Figure 5



Starting with conservation of energy, **derive** an equation for the spring constant *k*. Express your answer in terms of M, θ, D, and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

C. Figure 6 shows a graph of the energy of the system as a function of the position of the block from $x = 8D$ to $x = 12D$. The spring potential energy U_s of the block-spring-Earth system is shown on the graph.

On the axes shown in Figure 6, do the following.

i. **Sketch** and **label** a line or curve that represents the total mechanical energy E for the block-spring-Earth system as a function of the position of the block from $x = 8D$ to $x = 12D$.

ii. **Sketch** and **label** a line or curve that represents the gravitational potential energy U_g for the block-spring-Earth system as a function of the position of the block from $x = 8D$ to $x = 12D$.

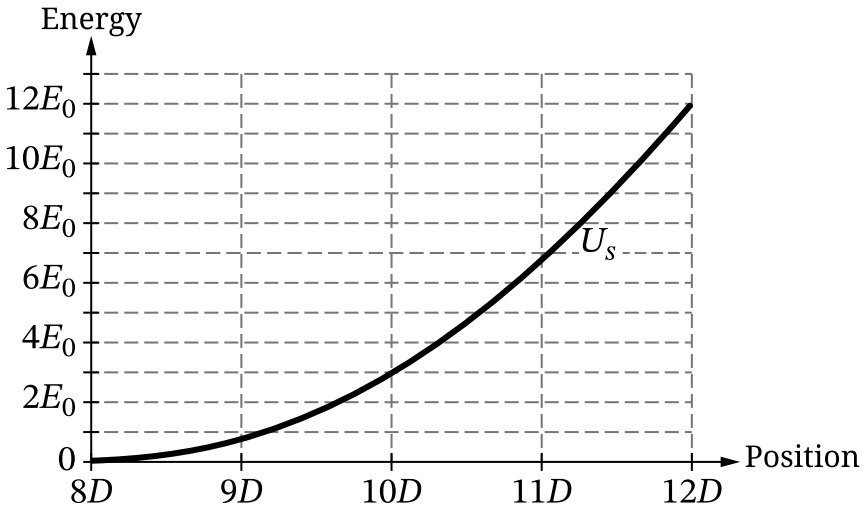


Figure 6

D. Indicate whether the speed v_{9D} of the block at $x = 9D$ is greater than, less than, or equal to the speed v_{8D} of the block at $x = 8D$.

_____ $v_{9D} > v_{8D}$

_____ $v_{9D} < v_{8D}$

_____ $v_{9D} = v_{8D}$

Justify how your response is consistent with the energy lines or curves you drew in Figure 6 in part C.