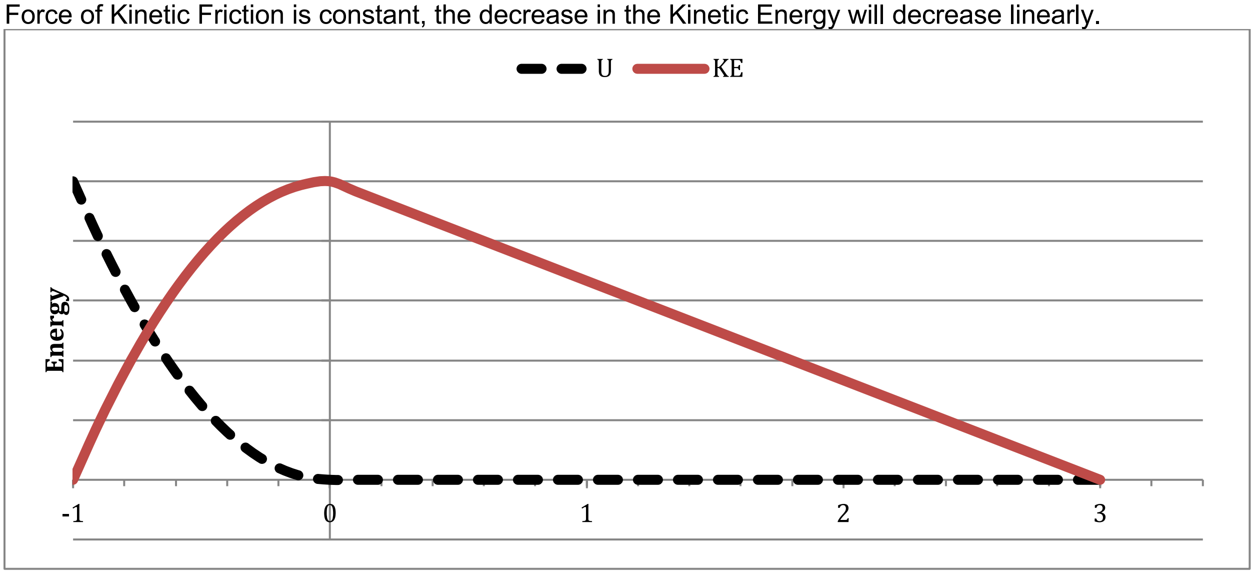
Flipping Physics Lecture Notes:

Free Response Question #3 - AP Physics 1 - 2015 Exam Solutions
http://www.flippingphysics.com/ap1-2015-frq3.html

(a i) & (a ii) At x = -D the velocity of the block is zero; it starts at rest. Therefore, the Kinetic Energy at x = -D is zero. The spring is compressed to its maximum magnitude; x = -D, therefore the Elastic Potential Energy is at its maximum value, $PE_e = U = \frac{1}{2}kx^2 = \frac{1}{2}k\left(-D\right)^2 = \frac{1}{2}kD^2 = U_{\max}$. Because the Elastic Potential Energy is proportional to x^2, it will decrease as an x^2 function from -D to 0. There is no friction and no force applied, therefore the total mechanical enery is conserved. This means the Elastic Potential Energy will be completely converted to Kinetic Energy as the block goes from x = -D to x = 0. Therefore Kinetic Energy will increase as an x^2 function.

At x = 0, the Elastic Potential Energy is zero: $PE_e = U = \frac{1}{2}kx^2 = \frac{1}{2}k\left(0\right)^2 = 0$, therefore the Kinetic Energy is now at its maximum value and has the same value as the Elastic Potnetial Energy at x = -D.

There is now friction as the block goes from x = 0 to x = +3D. The spring is no longer compressed, so there is no Elastic Potential Energy. Because $W_{friction} = \Delta ME \Rightarrow F_{kf} d\cos\theta = ME_f - ME_i = 0 - \frac{1}{2}kD^2$, (zero line at center of mass of block, initial point at x = -D and final point at x = 3D) the force of kinetic friction will do work on the block to convert the Kinetic Energy completely to heat and sound. Because the Force of Kinetic Friction is constant, the decrease in the Kinetic Energy will decrease linearly.



(b i) The student is correct that, because the spring is compressed more than before, it will have more energy when it leaves the spring so it will slide farther.

(b ii) The student is incorrect that double the compression will result in double the distance. The elastic potential energy stored in the spring follows $\frac{1}{2}kx^2$, which is not a linear relationship for x.

Part (c): Use the work due to friction equation again: 1 denotes when Δx = -D & 2 when Δx = -2D

$$F_{kf}d_1\cos\theta = 0 - \frac{1}{2}kD^2 \Rightarrow F_{kf}d_1\cos(180) = -\frac{1}{2}kD^2 \Rightarrow d_1 = \frac{kD^2}{2F_{kf}}$$

$$F_{kf}d_2\cos\theta = 0 - \frac{1}{2}k(-2D)^2 \Rightarrow F_{kf}d_2\cos(180) = -\frac{1}{2}k(4D^2) \Rightarrow d_2 = 4\frac{kD^2}{2F_{kf}} = 4d_1$$

Therefore the block will slide 4 times as far as before. $d_2 = 4d_1 = 4(3D) = \boxed{12D}$

(d) The student is correct that the block will have more energy when compressed farther. $U_1 = \frac{1}{2}kD^2$ & $U_2 = \frac{1}{2}k(4D^2) = 2kD^2$, therefore $U_2 > U_1$. The student is also correct that the block will slide farther along the track before stopping because the Force of Kinetic Friction remains the same and the work done by friction to stop the block will be increased because the amount of initial potential energy is increased. Therefore because $W_{friciton} = F_{kf}d\cos\theta = 0 - ME_i$, the displacement, "d", must increase because the initial mechanical energy increased. The student is incorrect that the stopping distance will be linearly increased because the energy is not linearly increased; the energy is increased as the square of the distance because $PE_e = U = \frac{1}{2}kx^2$.