Potential energy is the energy that a body possesses due to its **location** in space, while kinetic energy is the energy that it has depending on its **speed** through space. For locations within a few hundred kilometers of Earth's surface, and for speeds that are small compared to that of light, we have the two energy formulae:

$$P.E = mgh \qquad K.E = \frac{1}{2}mV^2$$

where g is the acceleration of gravity near Earth's surface and has a value of 9.8 meters/sec^2. If we use units of mass, **m**, in kilograms, height above the ground, **h**, in meters, and the body's speed, **V**, in meters/sec, the units of energy (P.E and K.E.) are Joules.

As a baseball, a coasting rocket, or a stone dropped from a bridge moves along its trajectory back to the ground, it is constantly exchanging, joule by joule, potential energy for kinetic energy. Before it falls, its energy is 100% P.E, while in the instant just before it lands, its energy is 100% K.E.

Problem 1 - A baseball with m = 0.145 kilograms falls from the top of its arc to the ground; a distance of 100 meters. A) What was its K.E., in joules, at the top of its arc? B) What was the baseball's P.E. in joules at the top of the arc?

Problem 2 - The Ares 1-X capsule had a mass of 5,000 kilograms. If the capsule fell 45 kilometers from the top of its trajectory 'arc', how much kinetic energy did it have at the moment of impact with the ground?

Problem 3 - Suppose that the baseball in Problem 1 was dropped from the same height as the Ares 1-X capsule. What would its K.E. be at the moment of impact?

Problem 4 - From the formula for K.E. and your answers to Problems 2 and 3, in meters/sec to two significant figures; A) What was the speed of the baseball when it hit the ground? B) What was the speed of the Ares 1-X capsule when it landed? C) Discuss how your answers do not seem to make 'common sense'.

Problem 5 - Use the formulae for P.E. and K.E. to explain your answers to Problem 4. (Hint: Don't worry about air resistance!!)

Problem 1 - A baseball with m = 0.145 kilograms falls from the top of its arc to the ground; a distance of 100 meters. A) What was its K.E., in joules, at the top of its arc? B) What was the baseball's P.E. in joules at the top of the arc?
Answer: A) K.E = 0 B) P.E. = mgh = (0.145) x (9.8) x (100) = 142 joules.

Problem 2 - The Ares 1-X capsule had a mass of 5,000 kilograms. If the capsule fell 45 kilometers from the top of its trajectory 'arc', how much kinetic energy did it have at the moment of impact with the ground?
Answer: At the ground, the capsule has exchanged all of its potential energy for 100% kinetic energy so K.E. = P.E. = mgh. Then K.E. = (5,000 kg) x (9.8) x (45,000 meters) = 2.2 billion joules for the Ares 1-X capsule.

Problem 3 - Suppose that the baseball in Problem 1 was dropped from the same height as the Ares 1-X capsule. What would its K.E. be at the moment of impact?
Answer: its K.E. would equal 100% of its original P.E. so K.E = mgh = (0.145 kg) x (9.8) x (45,000 meters) = 64,000 joules for the baseball.

Problem 4 - From the formula for K.E. and your answers to Problems 2 and 3, in meters/sec to two significant figures; A) What was the speed of the baseball when it hit the ground? B) What was the speed of the Ares 1-X capsule when it landed? C) Discuss how your answers do not seem to make 'common sense'.
Answer; A) Baseball: $E = 1/2\ m\ V^2$

$V = (2E/m)^{1/2}$

$= (2(64000)/0.145))^{1/2}$

= 940 meters/sec.

B) Capsule: $V = (2\ (2{,}200{,}000{,}000)/5{,}000)^{1/2}$

= 940 meters/sec

C) Our intuition suggests that the much heavier Ares 1-X capsule should have struck the ground at a far-faster speed!

Problem 5 - Use the formulae for P.E. and K.E. to explain your answers to Problem 4.
Answer: The P.E. that it starts with will be equal to the K.E when it lands, so P.E. = K.E. Comparing the formulae, we see that

$$mgh = \frac{1}{2}mV^2$$

And since, by algebra, the variables representing mass, m, cancel from both sides, we get

$$gh = \frac{1}{2}V^2$$

so the speed upon impact, V, depends only upon the constant g, and the height from which the body fell, h. Q.E.D.

Note: The above discussion is modified slightly when air resistance is considered.