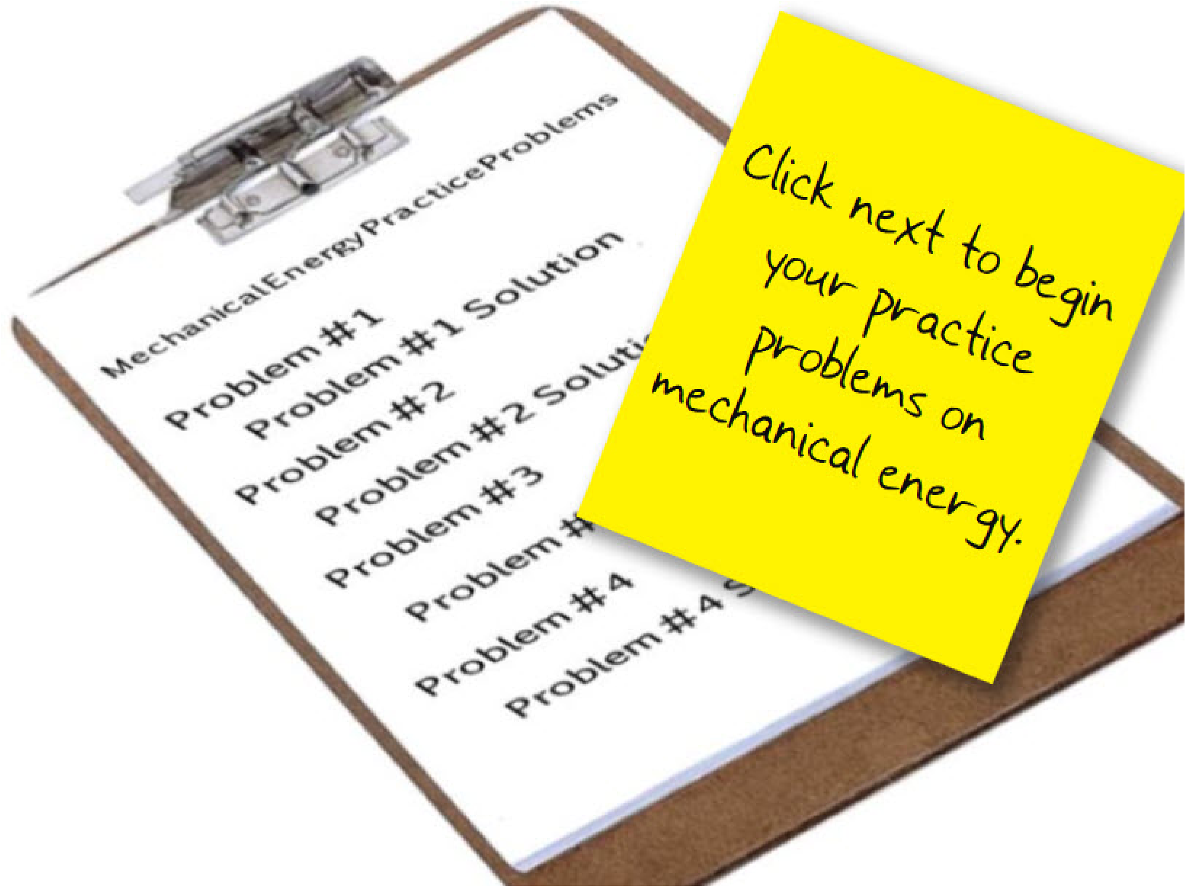
Module 4: Energy
Topic 4 Content: Mechanical Energy Practice Solutions



Introduction

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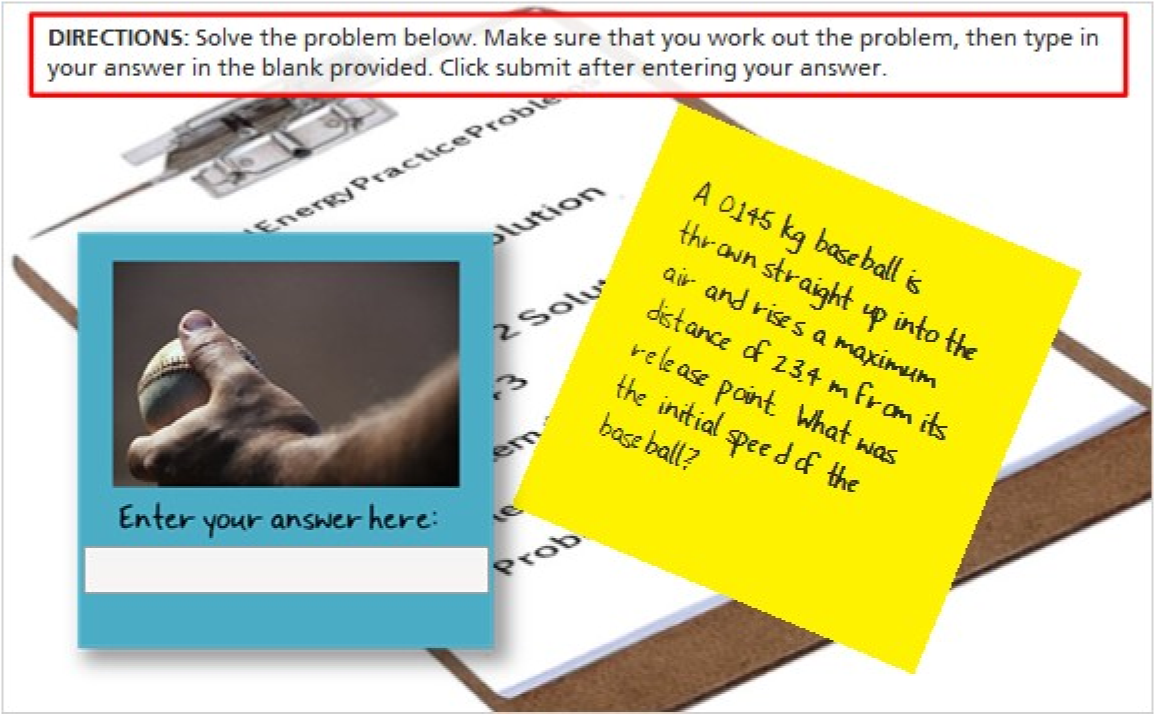
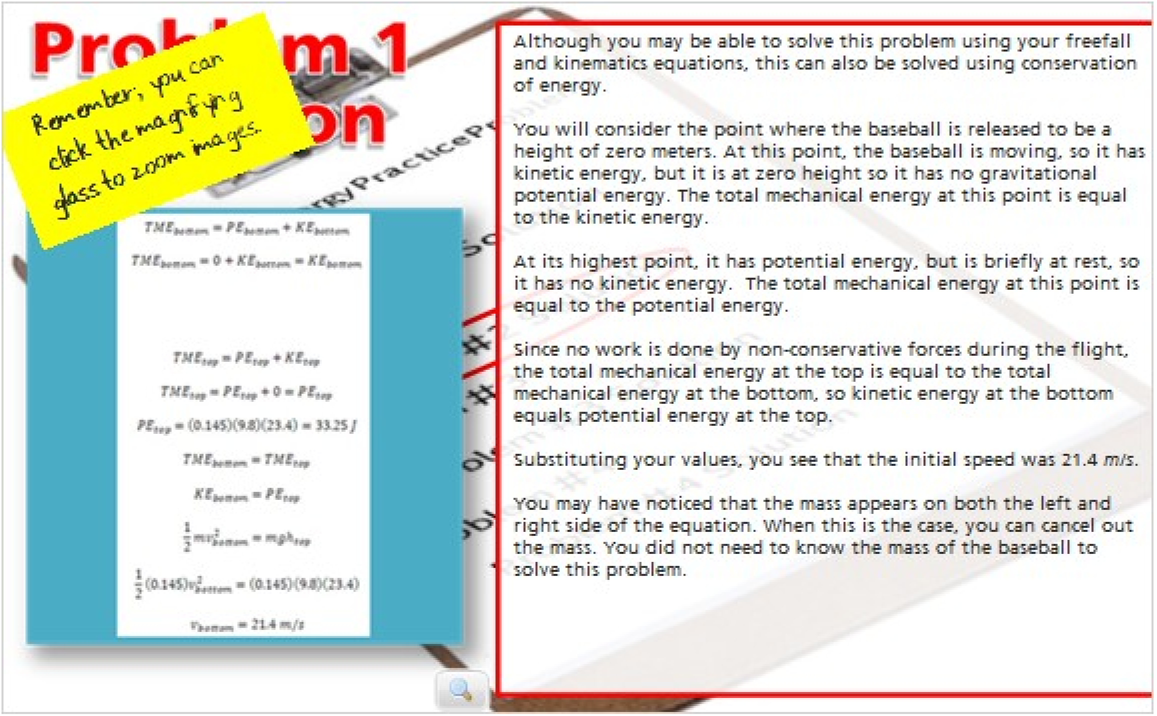


Problem 1

A zero point one four five kilogram baseball is thrown straight up into the air and rises a maximum distance of twenty three point four meters from its release point. What was the initial speed of the baseball?



Problem 1 Solution

Although you may be able to solve this problem using your freefall and kinematics equations, this can also be solved using conservation of energy.

You will consider the point where the baseball is released to be a height of zero meters. At this point, the baseball is moving, so it has kinetic energy, but it is at zero height so it has no gravitational potential energy. The total mechanical energy at this point is equal to the kinetic energy.

At its highest point, it has potential energy, but is briefly at rest, so it has no kinetic energy. The total mechanical energy at this point is equal to the potential energy.

Since no work is done by non-conservative forces during the flight, the total mechanical energy at the top is equal to the total mechanical energy at the bottom, so kinetic energy at the bottom equals potential energy at the top.

Substituting your values, you see that the initial speed was 21.4 meters per second.

You may have noticed that the mass appears on both the left and right side of the equation. When this is the case, you can cancel out the mass. You did not need to know the mass of the baseball to solve this problem.

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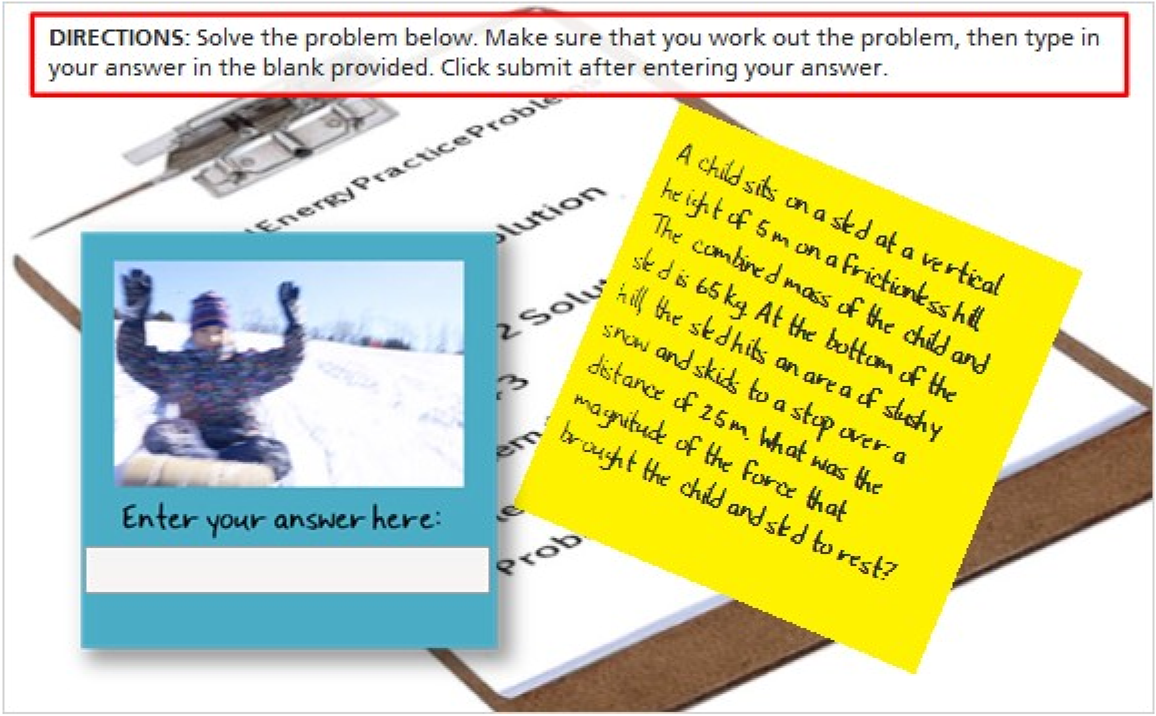
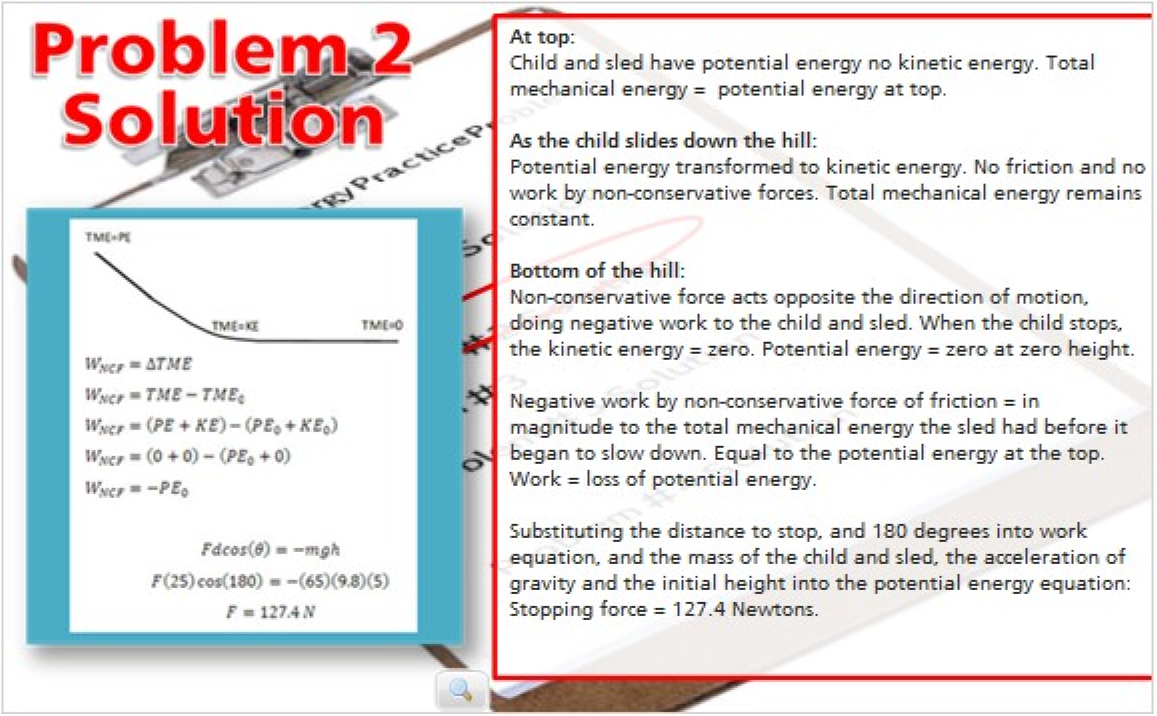


Problem 2

A child sits on a sled at a vertical height of 5 meters on a frictionless hill. The combined mass of the child and sled is sixty five kilograms. At the bottom of the hill, the sled hits an area of slushy snow and skids to a stop over a distance of twenty five meters. What was the magnitude of the force that brought the child and sled to rest?



Problem 2 Solution

At the top of the hill, the child and sled have potential energy, but they are at rest, so they have no kinetic energy. The total mechanical energy is equal to the potential energy at the top of the hill.

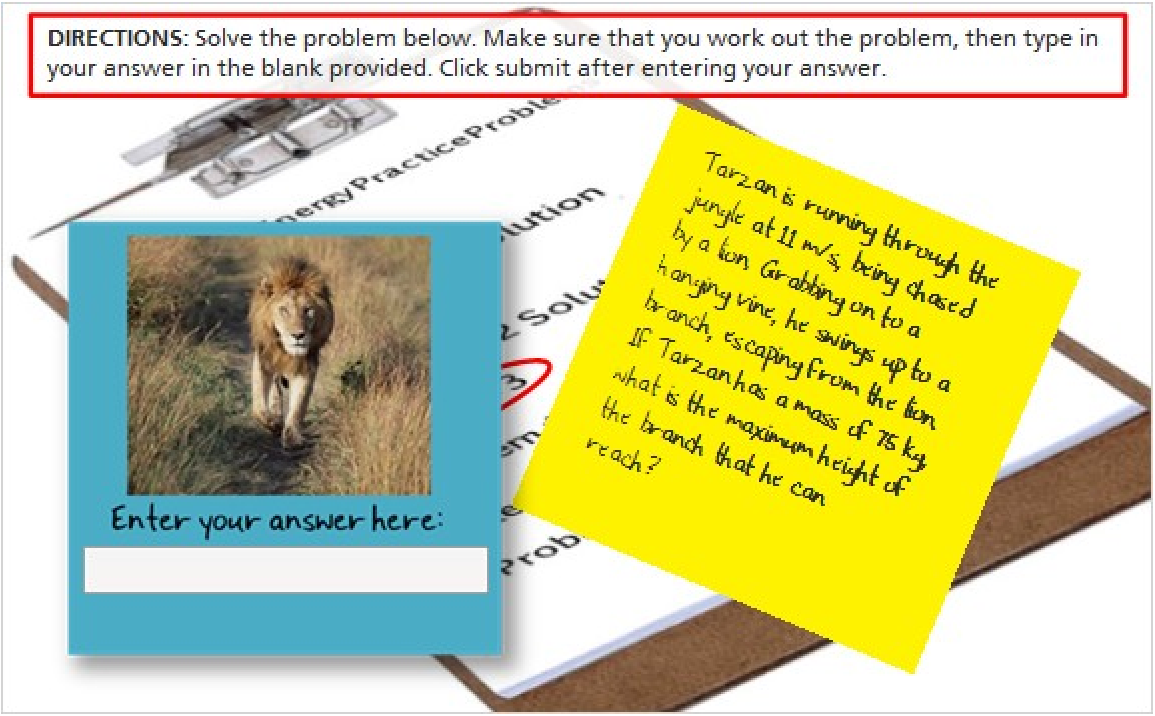
As the child slides down the hill, potential energy is transformed to kinetic energy, but there is no friction and no work is done by non-conservative forces, so the total mechanical energy remains constant.

After reaching the bottom of the hill, a non-conservative force acts opposite the direction of motion, doing negative work to the child and sled. When the child stops, the kinetic energy is again zero, and the potential energy is also zero, as he is at zero height.

The amount of negative work done by the non-conservative force of friction must be equal in magnitude to the total mechanical energy the sled had before it began to slow down. This is equal to the potential energy at the top of the hill.

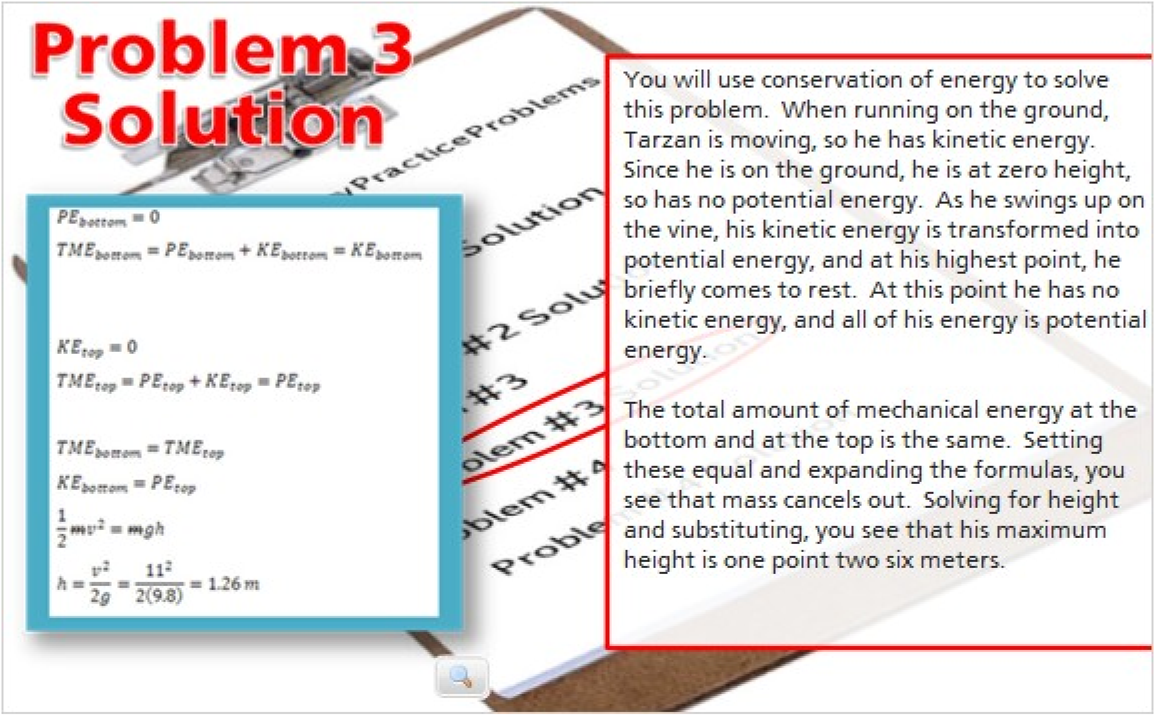
You therefore set work equal to the loss of potential energy.

Substituting the distance to stop, and one hundred eighty degrees into your work equation, and the mass of the child and sled, the acceleration of gravity and the initial height into the potential energy equation, you solve and find that the stopping force has a magnitude of one hundred twenty seven point four Newtons.



Problem 3

Tarzan is running through the jungle at eleven meters per second, being chased by a lion. Grabbing on to a hanging vine, he swings up to a branch, escaping from the lion. If Tarzan has a mass of seventy five kilograms, what is the maximum height of the branch that he can reach?



Problem 3 Solution

You will use conservation of energy to solve this problem. When running on the ground, Tarzan is moving, so he has kinetic energy. Since he is on the ground, he is at zero height, so has no potential energy. As he swings up on the vine, his kinetic energy is transformed into potential energy, and at his highest point, he briefly comes to rest. At this point he has no kinetic energy, and all of his energy is potential energy.

The total amount of mechanical energy at the bottom and at the top is the same. Setting these equal and expanding the formulas, you see that mass cancels out. Solving for height and substituting, you see that his maximum height is one point two six meters.

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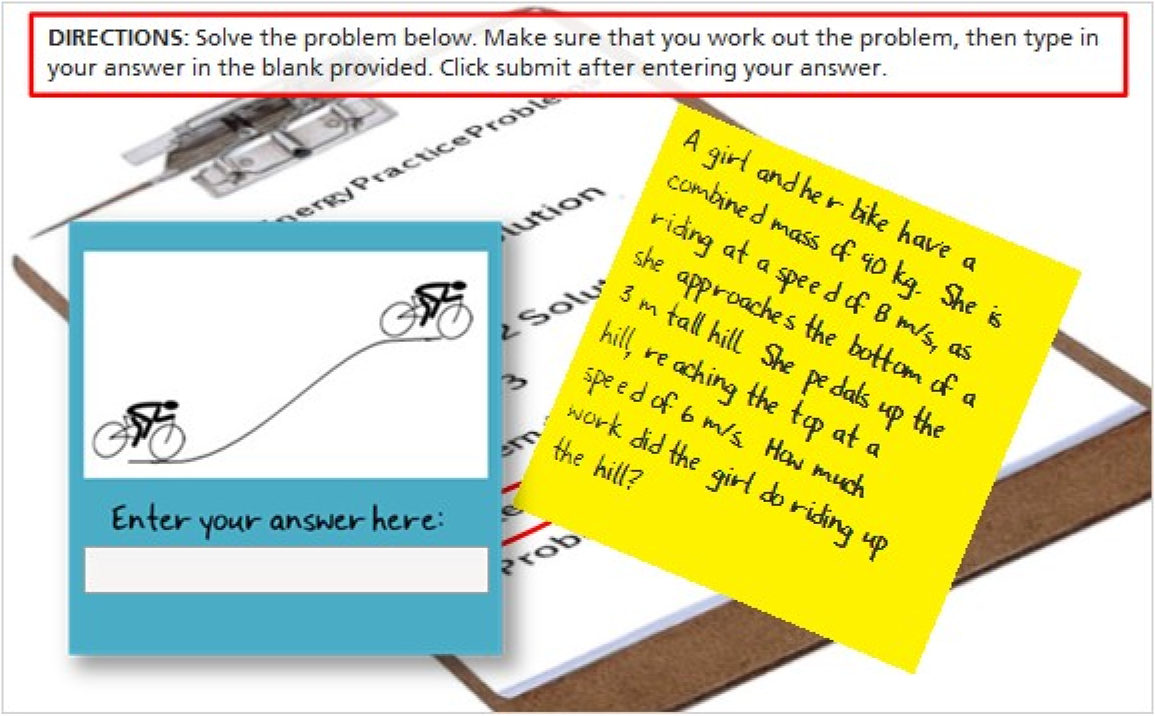

Problem 4

A girl and her bike have a combined mass of ninety kilograms. She is riding at a speed of eight meters per second, as she approaches the bottom of a three meter tall hill. She pedals up the hill, reaching the top at a speed of six meters per second. How much work did the girl do riding up the hill?

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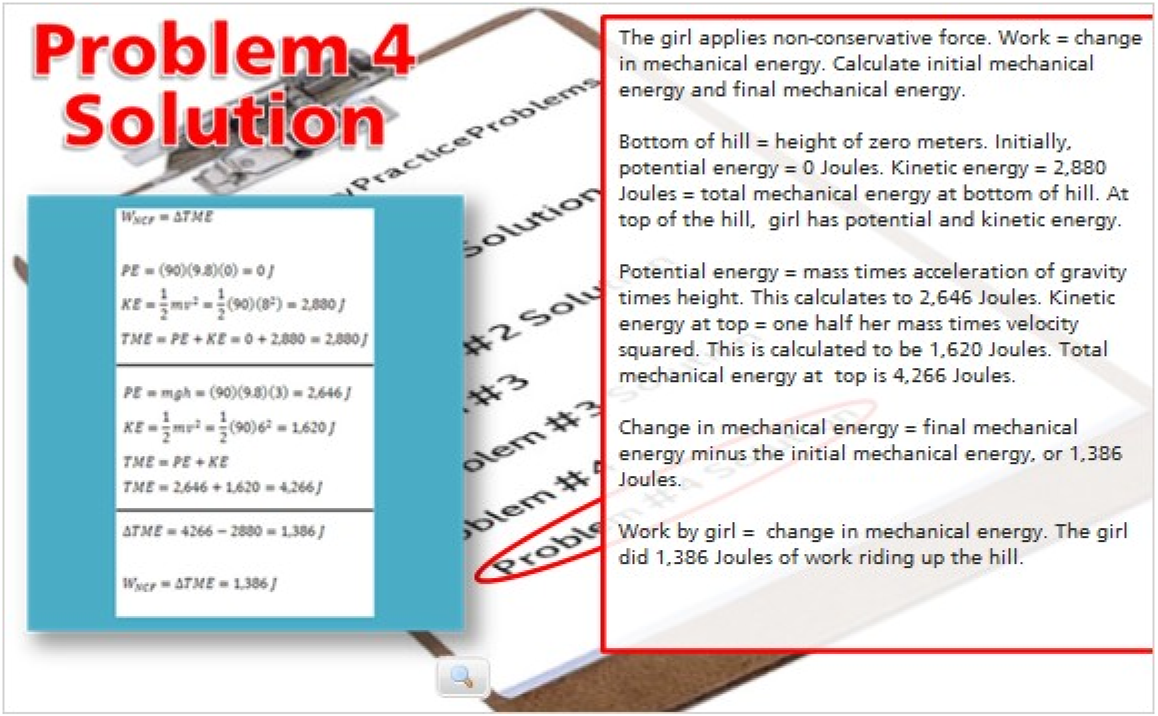

Problem 4 Solution

The girl applies a non-conservative force to the pedals, so the work done by the girl is equal to the change in mechanical energy. So you need to calculate the initial mechanical energy and the final mechanical energy.

You'll consider the bottom of the hill to be at a height of zero meters.

Initially, the potential energy is zero Joules. The kinetic energy is calculated to be two thousand eight hundred eighty joules, which is also the total mechanical energy at the bottom of the hill.

At the top of the hill, the girl has both potential and kinetic energy.

The potential energy is the mass times the acceleration of gravity times the height. This calculates to two thousand six hundred forty six Joules. The kinetic energy at the top is equal to one half her mass times velocity squared. This is calculated to be one thousand six hundred and twenty joules.

The total mechanical energy at the top is four thousand two hundred sixty six Joules.

The change in mechanical energy will be the final mechanical energy minus the initial mechanical energy, or one thousand three hundred eighty six Joules.

The work done by the girl equals the change in mechanical energy, so we can see that the girl did one thousand three hundred eighty six Joules of work riding up the hill.