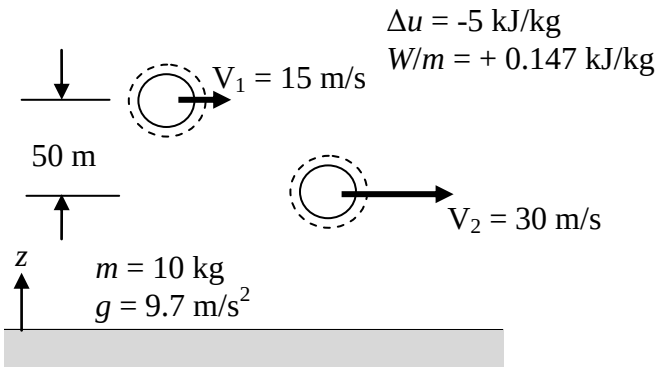
Problem 2.58

A closed system of mass of 10 kg undergoes a process during which there is energy transfer by work from the system of 0.147 kJ per kg, an elevation decrease of 50 m, and an increase in velocity from 15 m/s to 30 m/s. The specific internal energy decreases by 5 kJ/kg and the acceleration of gravity is constant at 9.7 m/s^2. Determine the heat transfer for the process, in kJ.

KNOWN: Data are provided for a closed system undergoing a process involving work, heat transfer, change in elevation, and change in velocity.

FIND: Determine the heat transfer for the process.

SCHEMATIC AND GIVEN DATA:



ENGINEERING MODEL: (1) The system is a closed system. (2) The acceleration of gravity is constant.

ANALYSIS:

$\Delta U + \Delta PE + \Delta KE = Q - W \quad \rightarrow \quad Q = \Delta U + \Delta PE + \Delta KE - W$

✓ $W = m\,[W/m] = 10\text{ kg}\,[-0.147\text{ kJ/kg}] = -1.47\text{ kJ}$

✓ $\Delta U = m\Delta u = 10\text{ kg}\,[-5\text{ kJ/kg}] = -50\text{ kJ}$

✓ $\Delta KE = \frac{m}{2}(V_2^2 - V_1^2) = \frac{10\text{ kg}}{2}\left[\left(30\ \frac{\text{m}}{\text{s}}\right)^2 - \left(15\ \frac{\text{m}}{\text{s}}\right)^2\right]\left|\frac{1\text{ N}}{1\text{ kg·m/s}^2}\right|\left|\frac{1\text{ kJ}}{10^3\text{ N·m}}\right| = +3.38\text{ kJ}$

✓ $\Delta PE = mg(z_2 - z_1) = (10\text{ kg})\,(9.7\text{ m/s}^2)(-50\text{ m})\left|\frac{1\text{ N}}{1\text{ kg·m/s}^2}\right|\left|\frac{1\text{ kJ}}{10^3\text{ N·m}}\right| = -4.85\text{ kJ}$

$Q = (-50) + (-4.85) + (3.38) - (-1.47) = -50\text{ kJ (out)}$ ←