Problems

2^{nd} week

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1) Consider a system having a mass of 1 kg whose velocity increases from 15 m/s to 30 m/s while its elevation decreases by 10 m at a location where g = 9.7 m/s^2. Calculate KE and PE.

$$\Delta K.E. = \frac{1}{2} m (\Delta V)^2$$
$$= \frac{15^2}{2}$$
$$= \frac{225}{2}$$
$$= 112.5 \ [J]$$

$$\Delta P.E. = mg \Delta z$$
$$= 9.7 \times -10$$
$$= -97.0 \ [J]$$

2) What is the power needed for a bicyclist traveling at 8.94 m/s to overcome the drag force imposed by the surrounding air?
The aerodynamic drag force is given by

$$W_d = \frac{1}{2} C_d A \rho V^2$$

C_d is the drag coefficient.
A is the frontal area of the bicycle and rider.
ρ is the air density.
$[C_d = 0.88,\ A = 0.362\ m^2,\ and\ \rho = 1.2\ kg/m^3]$

$$\dot{W} = W_d \cdot V$$
$$= \frac{1}{2} C_d A \rho V^2 \cdot V^2$$
$$= \frac{1}{2} C_d A \rho V^3$$
$$= \frac{1}{2} \times 0.88 \times 0.362\ m^2 \times 1.2\ kg/m^3 \times 8.94\ m^3/s^3$$
$$= 136.57\ [J/s]$$

$3kg$

3) Three kilograms of a certain gas is contained within a piston–cylinder assembly. The gas undergoes a process for which the pressure–volume relationship is

$$pV^{1.5} = constant$$

$10^5 Pa$

The initial pressure is 3 bar, the initial volume is 0.05 m³, and the final volume is 0.3 m³. The change in specific internal energy of the gas in the process is $u_2 - u_1 = -3.2 \times 10^3$ J/kg. There are no significant changes in kinetic or potential energy. Determine the net heat transfer for the process, in kJ.

$$pV^{1.5} = P_1 V_1^{1.5}$$

$$p = P_1 V_1^{1.5} \cdot \frac{1}{V^{1.5}}$$

$$= 3\times10^5 \cdot 0.05^{1.5} \times \frac{1}{V^{1.5}}$$

$$W = \int_{V_1}^{V_2} p\,dV$$

$$= 3\times10^5 \times 0.05^{1.5} \int_{V=0.05}^{V=0.3} \frac{1}{V^{1.5}}\,dV$$

$$= 3\times10^5 \times 0.05^{1.5} \times \left(\frac{1}{-1.5+1} V^{-1.5+1} \Big|_{V=0.05}^{V=0.3} \right)$$

$$= 3\times10^5 \times 0.05^{1.5} \times (-2) \times \left(\frac{1}{\sqrt{0.3}} - \frac{1}{\sqrt{0.05}} \right) \fallingdotseq 1.775 \times 10^4 \text{ [J]}$$

Since $\Delta U = Q_{\text{transfer In system}} - W_{\text{done by system}}$

$$Q = \Delta U + W$$

$$= 3\times -3.2\times10^3 + 1.775\times10^4$$

$$\fallingdotseq 8.153 \times 10^3 \text{ [J]}$$

$$= 8.153 \text{ [kJ]}$$

4) Gas is enclosed in a vertical piston-cylinder system equipped with an electrical resistor. The piston is subject to a 1 bar pressure from the atmosphere and has a mass of 45 kg with a surface area of 0.09 m^2. When an electric current flows through the resistor, the gas volume gradually increases by 0.045 m^3 while maintaining a constant pressure. The mass of the gas is 0.27 kg, and its specific internal energy increases by 42 kJ/kg. Initially and finally, both the gas and piston are at rest. The piston-cylinder is made from a ceramic composite, which is a good insulator. Assume negligible friction between the piston and cylinder wall, and the local acceleration due to gravity is 9.81 m/s^2.

Determine the amount of heat transferred from the resistor to the gas, in kJ, considering (a) the gas alone, and (b) the gas and the piston.

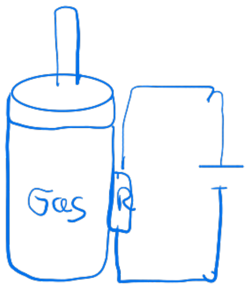
the system contain

Property

$P_{piston} = 10^5$ pa $m_{gas} = 0.27$ kg

$m_{piston} = 45$ kg

$A_{piston} = 0.09$ m^2



process

$\Delta V_{gas} = 0.045$ m^3 $\Delta P_{gas} = 0$ pa

(a) $\underset{\text{trasfer to gas}}{Q} = \Delta U + W_{\text{done by gas}}$

$W = \int_{V_1}^{V_2} P_{gas}\, dV$, $\Delta U = m_{gas} \times 42\,\text{kJ/kg}$

$= P_{gas}(\Delta V_{gas})$

equilibrium of pressure

$= P_{piston}(\Delta V_{gas})$

$\therefore Q = 10^5\,\text{pa} \times 0.045\,\text{m}^3 + 0.27\,\text{kg} \times 42 \times 10^3\,\text{J/kg}$

$= 15.840$ [kJ]

(b) $\overset{0}{\cancel{\Delta K.E.}} + \Delta P.E. + \Delta U = Q - W$

$\Delta P.E. = m_{piston} \times g \times \dfrac{\Delta V_{gas}}{A_{piston}}$ piston displacement

$= 45 \times 9.81 \times \dfrac{0.045}{0.09} = 220.725$ J

ΔU and W are the same as (a)

$\therefore Q = \Delta P.E. + \Delta U + W$

$= 220.725 + Q_{\text{from (a)}}$

$= 220.725 + 15.840 \times 10^3$

$= 16.060725 \times 10^3$

$\simeq 16.061$ [kJ]