MECH 3805 QUIZ 1.A Name: ___________________________________

Winter 2017 Monday Group

Student No: _______________________________

750 g of oxygen gas at an initial pressure of 1 MPa and initial temperature of 65°C expands in a piston-cylinder device following the relationship $Pv^{1.15}$=constant until its volume doubles. Draw a schematic of the process, state your assumptions, and find V_1, V_2, P_2, T_2 and $W_{1\text{-}2}$. (R_{Oxygen} = 0.26 kJ/kg.K)

MECH 3805 QUIZ 1.B Name: ________________________________
Winter 2017 Monday Group

Student No: ____________________________

750 g of oxygen gas at an initial pressure of 1 MPa and initial temperature of 75°C expands in a piston-cylinder device following the relationship $Pv^{1.15}$=constant until its volume doubles. Draw a schematic of the process, state your assumptions, and find V_1, V_2, P_2, T_2 and $W_{1\text{-}2}$.

SOLUTION 1.A

Assumptions:
Air is an ideal gas
Piston is leak proof and frictionless

$P_1V_1=mRT_1$ $R_{Oxygen} = 0.26$ kJ/kg.K

$V_1= [(0.75 \text{ kg})(0.26 \text{ kJ/kg.K})(273+65)\text{K}] / (1{,}000 \text{ kPa}) = 0.066 \text{ m}^3$

$V_2=2V_1=0.132\text{m}^3$

$P_2 = P_1(V_1/V_2)^{1.15} = (1{,}000 \text{ kPa})(1/2)^{1.15} = 451 \text{ kPa}$

$T_2=(P_2V_2/mR) = [(451 \text{ kPa})(0.132 \text{ m}^3)]/[(0.75 \text{ kg})(0.26\text{kJ/kg.K})] = 305 \text{ K}$

$W_{1\text{-}2} = (P_2V_2 - P_1V_1)/(1-n)$ (eq. 2.16c in textbook)

$W_{1\text{-}2}=[(451 \text{ kPa})(0.132\text{m}^3) – (1{,}000 \text{ kPa})(0.066\text{m}^3)]/(1-1.15) = 43.1 \text{ kJ}$

SOLUTION 1.B

Assumptions:
Air is an ideal gas
Piston is leak proof and frictionless

$P_1V_1=mRT_1$ $R_{Oxygen} = 0.26$ kJ/kg.K

$V_1= [(0.75 \text{ kg})(0.26 \text{ kJ/kg.K})(273+75)\text{K}] / (1{,}000 \text{ kPa}) = 0.068 \text{ m}^3$

$V_2=2V_1=0.136\text{m}^3$

$P_2 = P_1(V_1/V_2)^{1.15} = (1{,}000 \text{ kPa})(1/2)^{1.15} = 451 \text{ kPa}$

$T_2=(P_2V_2/mR) = [(451 \text{ kPa})(0.136 \text{ m}^3)]/[(0.75 \text{ kg})(0.26\text{kJ/kg.K})] = 315 \text{ K}$

$W_{1\text{-}2} = (P_2V_2 - P_1V_1)/(1-n)$ (eq. 2.16c in textbook)

$W_{1\text{-}2}=[(451 \text{ kPa})(0.136\text{m}^3) – (1{,}000 \text{ kPa})(0.068\text{m}^3)]/(1-1.15) = 44.4 \text{ kJ}$

MECH 3805 QUIZ 1.A Name: ___________________________________
Winter 2017 Friday Group

Student No: ______________________________

A jet of air with a mass flow rate of 10 kg/s, temperature of 300°C, velocity of 300 m/s, pressure of 500 kPa and an enthalpy of 800 kJ/kg enters a turbine. The potential energy of the air is negligible. R_{air} = 0.29 kJ/kg.K

- Draw a schematic of the system, state your assumptions
- Find the volume flow rate of the air and the rate of energy transfer to the system via the mass flow of the air.
- Does the negligible potential energy statement make sense? Discuss quantitatively.

MECH 3805	QUIZ 1.B	Name: ________________________________
Winter 2017	Friday Group	
		Student No: ____________________________

Air with a mass flow rate of 10 kg/s, temperature of 300°C, velocity of 400 m/s, pressure of 500 kPa and an enthalpy of 800 kJ/kg enters a turbine. The potential energy of the air is negligible. R_{air} = 0.29 kJ/kg.K

- Draw a schematic of the system, state your assumptions
- Find the volume flow rate of the air and the rate of energy transfer to the system via the mass flow of the air.
- Does the negligible potential energy statement make sense? Discuss quantitatively.

Solution 1.A

Assumption: air is an ideal gas

$P_1\dot{V}_1 = \dot{m}RT_1$

$(500\ kPa)(\dot{V}_1)\frac{m^3}{s} = \left(10\frac{kg}{s}\right)\left(0.29\frac{kJ}{kgK}\right)(300+273)K$

$\dot{V}_1 = 3.3\ m^3/s$

$\dot{E}_{massflow} = \dot{m}\left(h + \frac{1}{2}\vec{V}^2 + gz\right)$

$\dot{E}_{massflow}$ = (10 kg/s)(800,000 J/kg + (½)(300 m/s)^2+0) = 8,450,000 J/s = 8.45 MW

Most human settlements are at altitudes less than 1,000 m. Using g=10 m/s^2, the potential energy term would have a magnitude of about 10,000 J/kg. Compared to the sum of h and ke terms (800,000 kJ/kg + 45,000 kJ/kg), this is about 1%. So, it's ok to neglect.

Solution 1.B

Assumption: air is an ideal gas

$P_1\dot{V}_1 = \dot{m}RT_1$

$(500\ kPa)(\dot{V}_1)\frac{m^3}{s} = \left(10\frac{kg}{s}\right)\left(0.29\frac{kJ}{kgK}\right)(300+273)K$

$\dot{V}_1 = 3.3\ m^3/s$

$\dot{E}_{massflow} = \dot{m}\left(h + \frac{1}{2}\vec{V}^2 + gz\right)$

$\dot{E}_{massflow}$ = (10 kg/s)(800,000 J/kg + (½)(400 m/s)^2+0) = 8,800,000 J/s = 8.8 MW

Most human settlements are at altitudes less than 1,000 m. Using g=10 m/s^2, the potential energy term would have a magnitude of about 10,000 J/kg. Compared to the sum of h and ke terms (800,000 kJ/kg + 80,000 kJ/kg), this is about 1%. So, it's ok to neglect.

MECH 3805 QUIZ 1.C Name: ___________________________________

Winter 2017 Monday Group

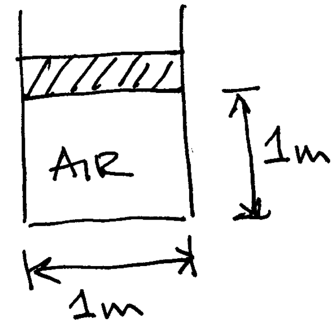
Student No: _______________________________

A piston-cylinder device with a diameter of 1 m and height (from the bottom of the piston to the bottom of the cylinder) of 1 m contains air at 20°C. The mass of the piston is 500 kg, and the acceleration due to gravity is 10 m/s^2. The local atmospheric pressure is 100 kPa. R_{air}=0.287 kJ/kg.K

Draw a schematic, state your assumptions and determine:

- the mass and specific volume of the air in the cylinder,
- the mass of a set of weights that needs to be added to the top of the piston so that the absolute pressure of the air in the cylinder is 250 kPa.

ASSUME:
FRICTIONLESS
PISTON



$D = 1m$

$H = 1m$

$T = 20°C = 293K$

$m_{PISTON} = 500 kg \quad g = 10 m/s^2$

$$A_{piston} = \frac{\pi D^2}{4} = 0.785\ m^2$$

$$V_{Piston-cylinder} = A \cdot H = 0.785\ m^3$$

$P_{ATM} = 100 kPa \quad R_{AIR} = 0.287\ kJ/kg.K$

$PV = mRT$

$$P_{DUE\ TO\ MASS} = \frac{F}{A} = \frac{mg}{A} = \frac{500kg \cdot 10m/s^2}{0.785\ m^2}$$

$$= 6369 Pa = 6.4 kPa$$

$$P_{AIR} = P_{ATM} + P_{DUE\ TO\ MASS} = 106.4\ kPa$$

$$m = \frac{PV}{RT} = \frac{106.4 kPa \times 0.785 m^3}{0.287 kJ/kg.K \times 293K} = 0.99\ kg \approx \underline{\underline{1 kg}}$$

$$v = \frac{V}{m} = \underline{\underline{0.785\ m^3/kg}}$$

$$P_{FINAL} = 250 kPa \qquad P_{DUE\ TO\ NEW\ MASS} = 250 - 106.4 = 143.6 kPa$$

$$m_{NEW\ MASS} = \frac{PA}{a} = \frac{143600\ Pa \times 0.785 m^2}{10\ m/s^2} = \underline{\underline{11,273\ kg}}$$