34

UNIVESITY OF SWAZILAND
FACULTY OF SCIENCE AND ENGINEERING
DEPARTMENT OF PHYSICS

Main Examination 2016/2017
COURSE NAME: Thermodynamics/Thermofluids
COURSE CODE: PHY242/EEE202
TIME ALLOWED: 3 hours

ANSWER ANY FIVE QUESTIONS. ALL QUESTIONS CARRY EQUAL MARKS

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35

Question 1

(a). A heat engine absorbs 360 J of energy and performs 25 J of work in each cycle. find

(i) The efficiency of the engine. [2 marks]

(ii) The energy expelled to the cold reservoir in each cycle. [2 marks]

(b). A particular engine has a power output of 5.0 kW and an efficiency of 25.0 %. Assuming the engine expels 8000 J of energy in each cycle, find

(i) The energy absorbed in each cycle. [3 marks]

(ii) The time for each cycle. [3 marks]

(c). The highest thermal efficiency of a certain engine is 30%. If the engine uses the atmosphere which has temperature of 300 K as its cold reservoir, what is the temperature of its hot reservoir? [4 marks]

(d). Suppose that a 1.0 kg of water at 0 °C is mixed with equal mass of water at 100 °C. After equilibrium is reached, the mixture has a uniform temperature of 50 °C. What is the change in entropy, ΔS, of the system?[4 marks]

(e). State Carnot's thoerem. [2 marks]

Question 2

36

(a). Define a **universe** in thermodynamics. [1 marks]

(b). What is the difference between **heat** and **temperature** in thermodynamics? [2 marks]

(c). What is the **specific heat capacity** of a substance. [2 marks]

(d). Define the following terms;

- (i) Isochoric (Isometric) process. [2 marks]
- (ii) Adiabatic process. [2 marks]
- (iii) Closed system. [2 marks]

(e). A 1.0 mol sample of an ideal gas is kept at 0.0°C during an expansion from 3.0 ℓ to 10.0 ℓ.

- (i) How much work is done during the gas expansion? [2 marks]
- (ii) How much energy transfer by heat occurs with the sarroundings in this process? [3 marks]
- (iii) If the gas is returned to the original volume by means of an isobaric process, how much work is done by the gas? [2 marks]

(f). What is the difference between **intensive** and **extensive** properties of a thermodynamic system? [2 marks]

Question 3

37

(a). A steel railroad track has a length of 30.0 m when the temperature is 0 °C. What is the length when its temperature is 40 °C? [2 marks]

(b). An ideal gas occupies a volume of 100 cm^3 at 20 °C and 100 Pa. find the number of moles of gas in the container. [2 marks]

(c). A spray containing a propellant gas at twice the atmospheric pressure (202 kPa) and having a volume of 125 cm^3 is at 22 °C. It is then tossed into an open fire. When the temperature of the gas in the can reaches 195 °C, what is the pressure inside the can? (*Assume any change in volume of the can is negligible*). [3 marks]

(d). Air, at 20 °C and 1.0 atm pressure, in the cylinder of a diesel engine is compressed from a volume of 800.0 cm^3 to a volume of 60.0 cm^3. Assume air behaves as an ideal gas with the ratio $\frac{C_p}{Cv} = 1.40$ and the compression is adiabatic. Find the final pressure and temperature of the air. [4 marks]

(e). One mole of an ideal gas is expanded isothermally and reversibly at T= 300 K from 10 atm to 1 atm. Calculate the work done. [4 marks]

38

(f). Consider a 3 m high, 5 m wide, and 0.3 m thick wall whose thermal conductivity is k = 0.9 W/(m·°C) (Fig. 1). On a certain day, the temperatures of the inner and the outer surfaces of the wall are measured to be 16°C and 2°C, respectively. Determine the rate of heat loss, $\dot{Q}$, through the wall on that day. [5 marks]

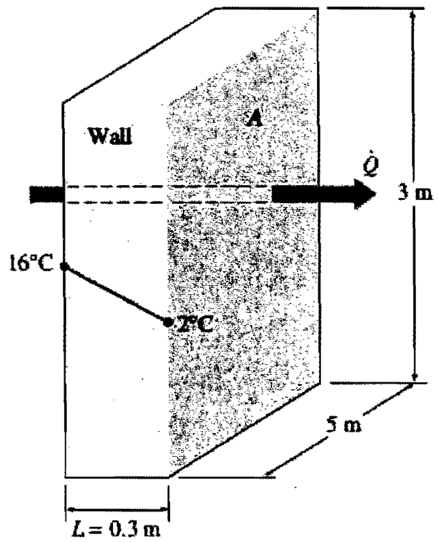

Figure 1:

Question 4

39

(a). One mole of ideal gas with constant heat capacity C_v is placed inside a cylinder. The cylinder is thermally insulated from the environment and inside the cylinder there is a piston which can move without friction along the vertical axis. Pressure, P_1 is applied to the piston. At some point, P_1 is abruptly changed to P_2 (e.g. by adding or removing a weight from the piston). As a result, the gas volume changes adiabatically.

(i) Show that $C_p - C_v = R$. [4 marks]

(ii) Show that the volume, V_2, can be expressed as $V_2 = \frac{RT_2}{P_2}$. Show that after equilibrium has been reached, the temperature, T_2, can be expressed as $T_2 = \frac{C_v P_1 + P_2 V_2}{C_p}$. [8 marks]

(*Hint: Use first law of thermodynamics* $\Delta E_{int} = \Delta Q - W, W = P\Delta V$, *and* $\Delta E_{int} = nC_v\Delta T$)

(b). After thermodynamic equilibrium has been established in (a), above, the pressure is abruptly reset to its original value P_1 . Compute final values of the temperature T_f and the volume V_f after the thermodynamic equilibrium has been reached again. Use the first law of thermodynamics and the adiabatic equation to compute the difference in temperatures $(T_f - T_1)$. [8 marks]

40

Question 5

(a). Show that while the slope of the fusion curve in a P-T diagram for substances that contract on freezing is positive, the slope of the fusion curve of the substances that expand on freezing is negative. [5 marks]

(b). Sketch a P-T diagram for both cases in (a) above. Designate the regions of the vapour, liquid and solid phases, the phase transition curves, the triple and the critical point. [5 marks]

(c). The latent heat of fusion of water at 0° C and 1 atm is $l_{12} = 3.34 \times 10^5$ J/kg. The volumes per gram in the solid and liquid phase are $v_1 = 1.09$ cm^3/g, $v_2 = 1.00$ cm^3/g respectively. Calculate the slope of the fusion curve (in atm/K) at 0° C. [5 marks]

(d). Assuming that the latent heat of fusion is approximately constant, and that the fusion curve in a P-T diagram is linear, calculate the pressure required to decrease the melting point of ice by 7.5° C. [5 marks]

Question 6

(a). An engine, with an ideal gas as the working substance, operates in the reversible cycle, $1 \to 2 \to 3 \to 1$, shown in figure 2. Assume that P_1 , V_1 and P_3 as well as heat capacity C_v are known.

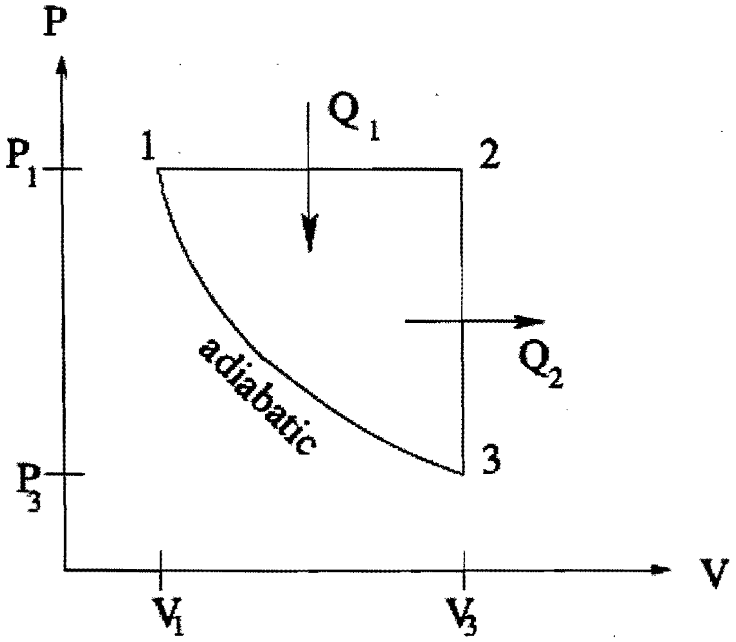

Figure 2:

(i) Calculate the work, the heat flow and the internal energy change for each leg of the cycle. [10 marks]

(ii) Calculate the entropy change for each leg of the cycle. What is the net change of the entropy? Why?[4 marks]

(iii) Define the efficiency of an engine. [2 marks]

(iv) Show that in our case the efficiency is given by

$$\eta = 1 - \frac{1}{\gamma}\left(\frac{1-\dfrac{P_3}{P_1}}{1-\dfrac{V_1}{V_3}}\right)$$

[4 marks]

where $\gamma = \dfrac{C_p}{C_v}$.

42

Appendix

Some usefull information

- $\frac{dP}{dT}|_{1\to 2} = \frac{l_{12}}{T(v_2 - v_1)}$
- $dU(S,V) = TdS - PdV$
- $F = U - TS$
- $G = U - TS + PV$
- $H = U + PV$
- $PV = nRT$
- $PV^\gamma = \text{const.}$
- $R = 8.31 J/\text{mol}^{-1}\text{K}^{-1}$. universal gas constant
- $k_B = 1.38 \times 10^{-23}\text{JK}^{-1}$. Boltzmann constant
- 1 atm $= 1.013 \times 10^5$ Pa
- Specific heat capacity of water= 4200 $\text{Jkg}^{-1}\text{K}^{-1}$
- Linear expansion coefficient for steel, $\alpha = 11 \times 10^{-6}$ $(°\text{C})^{-1}$,