][` ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~`

[Gay Lussac’s Law]

When you hear the term “Rigid” or “Rigid Cylinder”, then the volume is constant

Isobaric Process

Isothermal

Adiabatic process

For monoatomic gas,

For diatomic gas,

For triatomic gas,

For monoatomic ideal gas,

For diatomic gas,

For triatomic gas,

Thermodynamics is a sense is the relationship between heat, mechanical work and internal energy

**FIRST LAW OF THERMODYNAMICS**

[change in amount of energy contained within a system during some time interval] = [net amount of energy transferred in across the system boundary by heat transfer during the time interval] - [net amount of energy transferred out across the system boudary by work during the time interval]

In any process of a closed system, the energy of the system increases or decreases by an amount equal to the net amount of energy transferred across its boundary

A system is at steady state if none of its properties change with time. In real applications, when property variations with time are small enough to ignore, they are called steady state.

For a steady state system

TYPES OF SYSTEMS

1. Open Systems: In this system, matter can flow in or out of the system. Also, heat can flow in or out of the systsem.

2. Closed Systems: In this system, natter cannot flow in or out but energy can flow in or out of the system.

The equation ,is applied for closed systems

3. Isolated System: In this system, neither energy nor work can go in or out of the system

, ,

Change in total energy = Change in internal energy + Change in kinetic energy + Change in Potential Energy

Rate of heat transfer

**PROCESS IN THROMODYNAMICS**

This is the energetic development of a thermodynamic system proceeding from an initial state to a final state

Processes can be classified into Reversible and Irreversible processes

**TRAJECTORY IN THERMODYNAMICS**

Trajectory is also known as path. It it a way/path in which a process can be achieved.

For example, to make a chemical there are different steps you can take. The connection of all these steps is called the trajectory.

Initial state → Step1 → step2 → final state

initial state → Step1 → step4 → step3 → Final state

You can see that the initial and final states are the same but the path taken is different. This difference in path can affect work and heat in or out of the system.

**ENTHALPY**

This is the equivalent to the internal energy when applied to an open system. However, when working with closed systems, we don’t use enthalpy, we use the actual internal energy

Enthalpy is a created (or artificial) property.

Enthalpy helps us a lot to calculate process change

**QUALITY**

A vapour-liquid mixture is also called “**Wet Vapour**”

The **quality**, x of a vapour is essentially the percentage by mass of the vapour in the mixture (total).

At saurated liquid states,

At saturated vapour states,

Superheated refrigerant vapout is in a gaseous phasee. This phase occurs when the refrigerant continues to absorb heat beyond its saturation point at a constant pressure

Superheated refrigerant vapour and superheated water vapour are all superheated vapour phase

But

But

Dividing through by

But,

[Take note]

We can use the same theoretical concepts for other functions

For internal energy

For enthalpy

For entropy

For volume

Properties marked “lg” can be found in tables

If x=0, it is totally fluid

If x=1, it is totally gaseous

**VAPOUR TABLES**

When solving questions or equations on vapour tables, we are usually given a specific temperature and specific pressure and the values we are looking for are:

1. Specific Volume [usually in ]

2. Specific Enthalpy

3. Specific Internal Energy

4. Specific Entropy.

We are also looking for these values at different states like:

1. Saturated Ice

2. Saturated Liquid

3. Saturated Vapour

4. Sub-cooled solid

5. Sup-cooled liquid

6. Superheated Vapour

We will find all these data in vapour tables (typically) or in graphs (not common)

Saturated steam: This is steam and water in equilibrium. If you know the pressure, the temperature is automatically fixed and if you know the temperature, the pressure is automatically fixed.

Superheated Steam: You’ll need both the temperature and the pressure to solve your properties because you ae beyond vapour-liquid equilibrium.

Applying the Energy Balance using Property Tables

In applications where KE and PE effects are ignored, the energy balance for closed systems reduces to

For a case where a system consist

**IDEAL GAS MODEL**

In terms of mass,

Writing in terms of moles

is volume per mole

For any gas whose equation of state is given exactly by pv = RT, the specific internal energy depends on temperature only

Enthalpy is expressed as , this is for fluids

For an ideal gas, remember that

For an ideal gas model, it can be written as

NB: To verify that a gas can be modeled as an ideal gas,the states of interest can be located on a compressibility chart to determine how well the compressibility factor is satisfied

**PROPERTIES OF AN IDEAL GAS**

1. For a gas obeying the ideal gas model, specific heat (wrt volume) c\_v is also a function of temperature only

On integration, the change in specific internal energy is

2. Also, for a gas obeying the ideal gas model, the specific enthalpy depends only on temperature and so the specific heat (wrt pressure) c\_p is also a function of temperature only.

On integration, the change in specific internal energy is

**SPECIFIC HEAT RATIO**

Recall that,

On differentiating with respect to temperature,

The above equation shows that

For an ideal gas, the specific heat ratio, is a function of temperature only

For a polytropic process,

[for a closed system]

For an ideal gas,means

,

**ANALYSIS FOR OPEN SYSTEMS**

This is also called Control Volume Analysis

Recall that in an open system, mass can be transferred across its boundaries so it is important to calculate the mass flow rate

is the rate of flow of mass into the system across the inlet at time t

is the rate of flow of mass into the system across the exit at time t

is the time rate of change of mass contained within the system at time t.

In general, for cases of several inlets or outlets, the equation becomes

When a flowing stream of matter entering or exiting a control volume is,

1. Normal to the boundary

2. All intensive properties including velocity and density are taken as bulk average values over each inlet or exit area.

The flow is then said to be one-dimensional.

We are going to be assuming 1-d flow

When the flow is one-dimensional, the mass flow rate becomes

v→Velocity

Rewriting the equation in terms of specific volume, we have

The inverse of density is equal to specific volume

is called the **volumetric flow rate**.

For several inlets and exits

The steady-state assumtion is an idealization made during analysis of engineering systems. This means all properties are unchanging in time.

For this assumption,

Inlet mass flow rate is equal to exit mass flow rate.

Note that this is only for steady state.

OTHER THINGS TO NOTE

is the at the average temperature,

**SECOND LAW OF THERMODYNAMICS**

First Law:

Second Law: Irreversible processes tend to increase disorderliness of the system.

Irreversible and Reversible process.

An irreversible process: A ball falling down. This process is a spontaneous process because it happens naturally without any assistance.

However, a ball going up is not spontaneous.

Reversible process: A ball on a horizontal plane that can move both directions.

IN TERMS OF HEAT

Heat flows from hot to cold: A spontaneous process

Heat flow from cold to hot will be non-spontaneous doesn’t happen naturally and will need external energy to happen.

If both bodies have the same temperature, there is equilibrium and the same amount of energy is transferred both ways.

When you have an irreversible naturally process, the entropy and disorderliness tends to increase

Reversible process, the entropy is 0

When an imbalance exits between two systems, there is an opportunity for developing work that would have been lost if the systems are allowed to come into equilibrium in an uncontrollable way.

HEAT ENGINES

This is a device that converts heat energy to mechanical energy or work.

If we have a hot temperature connected to a system and an output of lower temperature. Heat will naturally flow from the hot to cold. The heat that would flow into the system is , the energy expelled by the system to the surrounding or low temperature reservoir . As heat flows from the hot to cold, the system can absorb some of the heat and convert it to work. The heat engine takes only a fraction of the heat absorbed and converts it to work. The remaining is expelled into the environment

Efficiency,

Power, in watt

Clausius Statement of 2nd Law

Kelvin-Planck Statement of the 2nd Law

Statements of thermodynamics

1. Heat flows from a hotter place to a colder place

2. Natural processes tend to lead to disordiliness. When systems are left alone, they tend to undergo spontaneous changes until a condition of equilibrium is achieved both internally and with their surroundings.

CARNOT CYCLE

This is basically the ideal model of a heat engine. No other engine can have an efficiency greater than that of the carnot engine as fas as we know.

REFRIGERATION CYCLES

Heat engine converts heat to mechanical work

Refrigerator is opposite. Electricity is used to perform work on the device and to pump heat from a cold reservoir to a hot reservoir

Coefficient of performance. This is a way of

The carnot coefficient of performance,

For a heat pump

Also,

**QUESTIONS TO SOLVE**

1. A closed system of mass 10kg undergoes a process during which there is energy transfer by work from the system of , an elevation decrease of and an increase in velocity from to . The specific internal energy decreases by 5kJ/kg and an acceleration due to gravity is . Determine the heat transfer for the process in kJ.

2.If the gas undergoes a process for which and , determine the heat transfer in kJ keeping the initial pressure and volume fixed.

Answer:

3. What is the quality of a liquid-vapour mixture

a. If there is a total amount of 123.6kg of water

b. We boil 87.5kg of that liquid to a vapour

4. During a steady state operation, a gearbox receives 60kW through the input shaft and delivers power through the output shaft. For the gearbox system, the rate of energy convection heat transfer is given by where . K is the transfer coefficient, is the outer surface of the gearbox, is the temperature of the outer surface and is the temperature of the surrounding air away from the immediate vicinity of the gearbox. For the gearbox , evaluate the heat transfer rate and power delivered through the output shaft in kW.

Answers:,

5. Four-tenths kilogram of a certain gas is contained within a piston-cylinder assembly. The gas undergoes a process for which the pressure-volume relationship is . The initial pressure is 3bar. The initial volume is and the final volume is . The change in specific internal energy of the gas in the process is . There are no significant changes in kinetic or potential energies. Determine the net heat transfer for the process.

Answers: ,

6. The quality of a two-phase liquid vapour mixture of water at 40C with specific volume of is what?

7. Determine the phase or phases in a system consisting of water at the following conditions

- p=10bar, T=179.9C Answer: Saturate vapour

- p=10bar, T=150C Answer: Superheated vapour phase(Superheated refrigerated vapour)

- p=0.5bar, T = 100C Answer: gas

- p=50bar, T=20C: Compressed Liquid

- p=1bar, T = -6C: Superheated refrigerant

8. Determine the specific volume in for the following properties and locate the states on a T-v diagram

- p = 20MPa, T = 400C Answer: 0.00994

- p = 20MPa, T = 40C Answer: 0.9992

- p=2MPa, T=40C Answer: 0.001004

9. Four kg of water at 100C fills a closed container having a volume of

a. If the water at this state is vapour, determine the pressure in bar

b. If the water is a two-phase liquid-vapour mixture, determine the quality

10. Using the tables for water, determine the specified property data at the indicated states.

- At p=2MPa, T=300C. Find u, in kJ/kg

- At p=2.5MPa, T=200C, Find u, in kJ/kg

- At p=1.5bar, T=100C

- p = 50bar, , Find h, in kJ/kg

- p=1bar, T=-6C

11. What is the saturation temperature of water vapour at a pressure 10MPa?

12. What is the specific volume of water vapour at 10MPa and 600C?

13. Determine the specific volume of water vapour at a state where p=10bar and T=215C

14. Consider a system consisting of a two-phase liquid-vapour mixture of water at 100C and a quality of 0.9. What is the specific volume of the mixture?

15. Evaluate the temperature, specific volume and enthalpy for water at 0.1MPa and a specific internal energy of 2537.3kJ/kg

9053264639

1MPa = 10bar

16. Air at , enters a well-insulated horizontal pipe having a diameter of 1.2cm and exits at temperature and pressure . Applying the ideal gas model for air at steady state, determine the following

a. Exit velocity

b. The mass flow rate

c. The inlet velocity

Solution:

For steady state,

Or

Since we are not given anything related to heat, work or potential energy, the new equation becomes

Recall,

For steady state,

From the above question, the area for both the inlet and the outlet are the same.

Recall that, PV=RT

From the property table,

d = 1.2cm = 0.012m

Dividing both sides by and applying the conversion factor

b.

17. Refrigerant 134a enters a horizontal pipe operating at steady state at , , . At the exit, the temperature is and with the pressure is . If the pipe diameter is , determine:

a. the mass flow rate from the refrigerant.

b. the velocity at the exit in

Solution:

d = 0.04m

Assuming a steady state

dot{m} = {{0.00} over {0.07518}}

18. Water enters the first inlet of a control volume (which has two inlets and one outlet) at , with a mass flow rate of 20kg/s. At the second inlet, with cross section area of

19. Evaluate the work, in kJ, for a two-step process consisting of an expansion with n=1.0 from ,

20. The net work of a power cycle is 10000kJ and the thermal efficiency is 0.4. Determine the heat transfers and in kJ

21. A feed-water heater operating at steady state has two inlets and one exit. At inlet 1, water vapour enters at p\_1 = 7{b{ar}}, T\_1 = 200C with a mass flow rate of 40kg/s. At inlet 2, liquid water at p\_2 = 7bar, T\_2 = 40C enters through Area A\_2 = 25cm^2. Saturated vapour at 7bar exits at outlet 3 with a volumetric rate of 0.06m^3/s. Determine the mass flow rates at inlet 2 and outlet 3 in kg/s. Also find the velocity at inlet 2

Solution

{dot{m}}\_1 = 40kg/s

{}\_1 =

m\_1 + m\_2 = m\_3

22. A heat engine absorbs 2500J of heat and discards 2100J of heat. Calculate the work performed by the engine and its thermal efficiency.

23. A jet engine releases 5000J of energy per cycle and performs 5000J of work

a. How much heat is absorbed by the engine per cycle. Answer:5800

b. What is the thermal efficiency

c. How much work can the engine perform in 50cycles: Answer 40,000J

d. If the engine completes each cycle in 0.20 seconds, what is the power rating: Answer: 4000W

24. 8000J of heat energy is absorbed per cycle by a diesel engine that is 15% efficient

a. How much work does it perform per cycle? Answer: 1200

b. How much energy does it expel to the environment per cycle. Answer: 6800J

25. An engine has a heat input of 175kW and a work output of 21kW

a. What is the thermal efficiency? Answer: 12%

b. At what rate is heat absorbed into the environment? Answer: 154kW

c. How much heat energy is released into the environment if the machine were to operate continuously for one day: Answer: 13305600J

26. A gasoline engine takes in 1200J of heat energy per cycle and produces 2400J of mechanical work

a. How much heat energy is removed per cycle? 9600

b. What is the efficiency. Answer: 20%

c. What mass of fuel is consumed in each cycle if the heat of combustion is 45000J/g. Answer 0.2667g

d. If the engine goes through 50cycles per second, what is the power rating in watts, kilowatts, horse power. Answer: 120,000W,160.9hp

1hp = 746W

27. A refrigerator uses 1200J of work to pump 3000J of heat from a cold reservoir at 275K to a heat reservoir at 320K

a. What is the coefficient of performance. 2.5

b. What is the maximum coefficient of performance. Answer: 6.1

c. How much heat is delivered to the hot reservoir. 4200J

28. A carnot freezer removes 1500J of heat energy from a reservoir at 250K and pumps it to a reservoir of 320K

a. How much heat energy is transferred to the heat reservoir? 1920

b. What is the coefficient of performance for the device? 3.57

29.