Thermodynamics:

(1): The temperature of human body shown by thermometer is 98.6° Fahrenheit. Determine the temperature in °C, K and Rankine range.

Soln:

Given,

Fahrenheit (°F) = 98.6°

We know,

$$\frac{C-0}{100-0} = \frac{F-32}{212-32} = \frac{R-492}{672-492} = \frac{K-273}{373-273}$$

$$\text{or, } \frac{C}{5} = \frac{F-32}{9} = \frac{R-492}{9} = \frac{K-273}{5}$$

Now,

$$C = \frac{5\times(98.6-32)}{9} \qquad \therefore C = 37°$$

$$K = C + 273 = 37 + 273° = 310\ K$$

$$\frac{37}{5} = \frac{R-492}{9}$$

$$\text{or } \frac{37\times 9}{5} + 492 = R \qquad \therefore R = 558.6°$$

2) Compressed air from higher pressure is released slowly to a large balloon. Emptying the cylinder fills the balloon to a volume of 25 m^3. What is the workdone by compressed air if atmospheric pressure is 101 kPa.

Soln:

Given,

initial volume (V_1) = ~~25 m^3~~ 0 m^3

final volume (V_2) = 25 m^3

Atmospheric pressure (P) = 101 kPa = 101×10^3 Pa

Now,

Total workdone (W) = $P(V_2 - V_1)$

$= 101 \times 10^3 \times 25$

$\therefore W = 2525$ KJ

3) Nitrogen gas at 300 K, 101 kPa and 0.1 m^3 is compressed slowly in an isothermal process to 500 kPa. Calculate the workdone during the process.

Soln,

Given,

$T = 300$ K

$P_1 = 101$ kPa = 101×10^3 Pa $\qquad V_1 = 0.1\, m^3$

P_2 = 500 kPa = 500×10^3 Pa. $\qquad V_2 = \frac{P_1}{P_2} \times V_1 = 0.02\, m^3$

R = 8.134 J/mol K.

So,

$W = RT \ln\left(\frac{P_1}{P_2}\right) = 8.314 \times 300 \times \ln\left(\frac{101 \times 10^3}{500 \times 10^3}\right) = -3989.44$ J

Negative sign gives compression.

<Q.4>: Gas expands in a cylinder according to relation, $PV^{1.3} = C$ from an initial state of $0.3 m^3$ and 1000 KPa to final state of 101 KPa. Calculate the workdone on the piston by the gas pressure.

Soln:

Given,

$PV^{1.3} = C \Rightarrow PV^{\gamma} = \text{constant}$.

This is adiabatic process.

Here,

$\gamma = 1.3$

$V_1 = 0.3 m^3$

$P_1 = 1000 kPa = 1000 \times 1000 = 10^6 Pa$

$P_2 = 101 \times 10^3 Pa$

$V_2 = \frac{P_1 \times V_1}{P_2} = 2.97 m^3$

Now,

$$W = \frac{C}{\gamma - 1}\left[\frac{1}{V_1^{\gamma-1}} - \frac{1}{V_2^{\gamma-1}}\right]$$

$$= \frac{P_1 V_1^{1.3}}{1.3-1}\left[\frac{1}{(0.3)^{1.3-1}} - \frac{1}{(2.97)^{1.3-1}}\right]$$

$$= \frac{0.3^{1.3} \times 10^6}{0.3} \times 0.713 = \cancel{0.49 \times 10^6 \, M}$$

$$= 0.49 \text{ MPa}.$$

<Q.5>: During the compression stroke an IC engine rejects 25 kJ/kg of heat to the cooling water. The work input to the stroke is 75 kJ/kg. Calculate the change in internal energy of working fluid.

Soln:

Given,

$Q_{out} = -25 kJ/kg = -25 \times 10^3 J/kg$ [∵ Heat is rejected]

$Q_{in} = -75 kJ/kg = -75 \times 10^3 J/kg$ [∵ work is supplied]

$\Delta U = ?$

We know, first law of thermodynamics,

$\Delta U = Q - W$

$= -25 - (-75)$

$\therefore \Delta U = 50 \cdot KJ$

<5>: Derive first law of thermodynamics in terms of enthalpy.

Soln:

From the definition of enthalpy,

$H = U + pV$.

For infinitesimal process change,

$$(H + dH) - H = [U + dU + (p + dp)(V + dV)] - (U + pV)$$

Expanding and dropping the quadratic terms in infinitesimals, we get.

$$dH = dU + p\,dV + V \cdot dp$$

We know, $dQ = dU + p\,dV$

Then,

$dH = dQ + V \cdot dp$

For quasi-static process,

$\therefore dH = dQ$.

<Q.7>: Write short notes on Perpetual Motion Machine Type II (PMM II). Why is it impossible to construct such machines?

Soln:

Perpetual motion machine II (PMM II) violates second law of thermodynamics.

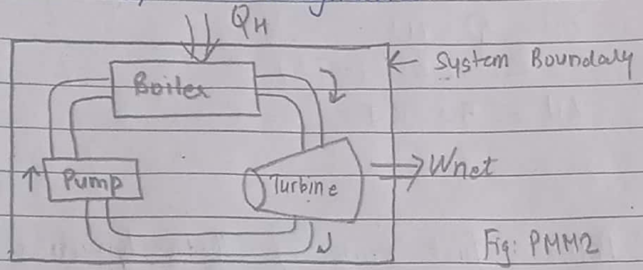


Fig: PMM2

Here, the boiler takes Q_H amount of heat and converts water to vapour. The vapour is passed to turbine which is then rotated.

The exhaust gases from turbine is pulled by pump and sent into the boiler.

In this case, the heat is never rejected to Q_2 and the machine is 100% efficient.

PMM2 violates second law as no machine can be 100% efficient.

<Q.8>: Describe the Refrigeration and Heat Pump Cycle with suitable graphical and schematic representation.

Soln:

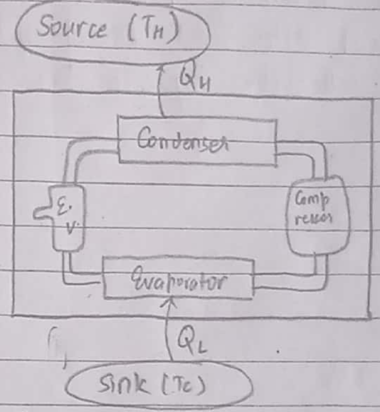


Fig: Working of Refrigerator

The compressor contricts the refrigerant vapour and raises its pressure.

It is passed to the coils on the outside of refrigerator. The hot gas loses heat to the source and the refrigerant cools down.

The refrigerant absorbs the heat from inside the fridge, cooling down the air. The refrigerant passes through expansion valve which ~~gree~~ decreases pressure and passes to evaporator. The evaporator takes heat from sink, is heated and the refrigerant is passed to compressor again.

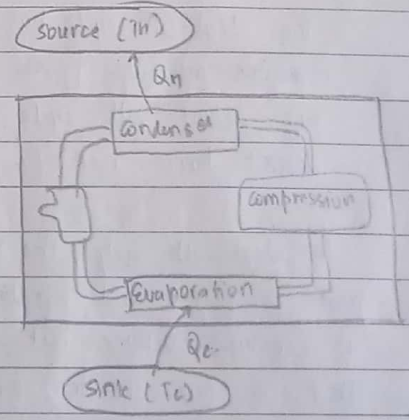


Fig: Working of Heat pump

The working fluid is passes to compressor an converts to high pressure gas.

In the condensor, the refrigerant loses heat to the source.

This high-pressure working fluid passes through the expansion valve that neutralizes the pressure and passes it to evaporator.

Here, the working fluid is heated by ~~heated~~ from sink and pass through compressor.

(9): Describe the deviation shown by practical Otto and Diesel cycles to the ideal Otto and Diesel cycles with suitable graphical and schematic representation.

Soln:

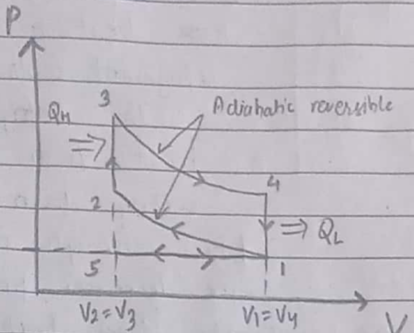


Fig. ideal otto cycle including intake & exhaust stroke

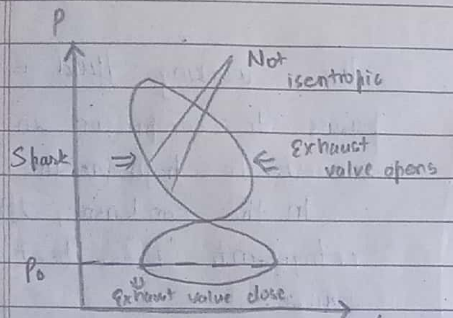
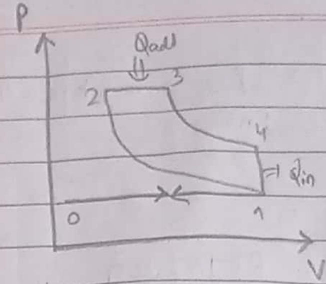


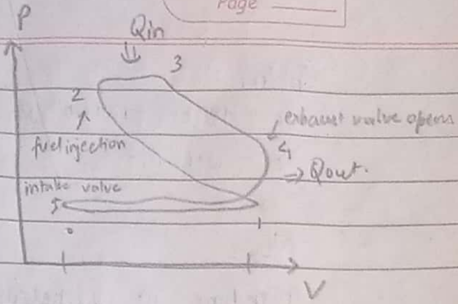
Fig. Actual otto cycle

- The ideal otto cycle has reversible adiabatic process but actual otto cycle doesn't have isentropic process.

- In ideal otto cycle, the ~~work~~ heat acceptance and rejection is at constant volume, but that is not the true for actual otto cycle.

- In ideal otto cycle, the curve ~~decreases~~ doesn't decrease below lower threshold of pressure, but in actual otto cycle, the pressure decreases below the lower threshold.





- Here, the workdone under the graph by ideal cycle is more than that of the actual cycle.

- The heat is ~~not~~ accepted ~~at~~ constant pressure ~~as~~ in ideal cycle but in actual diesel cycle, the heat absorbed is not at constant pressure.

- The heat rejected in ideal cycle is ~~in~~ at constant volume but that is not the case in actual diesel cycle.

10) Consider a gas enclosed in a piston cylinder arrangement. The gas is ~~actually~~ initially at 150 kPa and occupies volume $0.03\ m^3$. The gas is heated until the volume increases to $0.1\ m^3$. Calculate the workdone by gas if pressure is inversely proportional to pressure.

Soln:

Volume is inversely proportional to pressure at only constant temperature.

Hence, the ~~workdone~~ process is in isothermal process

Given,
$P_1 = 150\,kPa = 150\times10^3\ Pa$ $\qquad$ $P_2 = (P_1 \times V_1)/V_2 = 4.5\,kPa = 4.5\times10^3\ Pa$
$V_1 = 0.03\,m^3$ $\qquad$ $V_2 = 0.1\,m^3$

Now,
Workdone in isothermal process $(W) = \cancel{RT\ln\left(\frac{V_2}{V_1}\right)}$

$$= \cancel{8.314\times} = P \times dV$$
$$= P(V_2 - V_1)$$
$$= 150\times10^3 \times (0.1 - 0.03)$$
$$\therefore W = 10500\ J = 10.5\ kJ.$$

(11): What are the assumptions for air standard thermodynamic cycles?

Soln:

The assumptions for Air standard Thermodynamic cycles are as follows:

i) Working fluid circulating throughout the cycle is considered to be air and the air is considered ideal gas.
ii) Specific heat capacity of the air remains constant.
iii) The processes occurring within the cycle are internally reversible.
iv) The combustion process in the engine is replaced by heat addition from external source.
v) The ~~heat~~ exhaust process is replaced by heat rejection to the sink.

(Q.12): How are limitations of 1st law thermodynamics addressed by second law of thermodynamics?

Soln:

The limitations of 1st law thermodynamics addressed by 2nd law thermodynamics as follows:

(i): 1st law thermodynamics doesn't say the process is spontaneous or non-spontaneous process. 2nd law thermodynamics explains entropy and spontaneity of a process.

(ii): ~~2nd~~ 1st law thermodynamics doesn't explain the direction of heat flow. 2nd law thermodynamics predicts the spontaneous process of heat flow from higher temperature to lower temperature.

(iii) 1st law thermodynamic fails to give feasibility of thermodynamic process. 2nd law thermodynamics explains that spontaneous reactions are feasibility.

(Q.13): "Entropy of the universe is always increasing." - Explain.

Soln:

According to second law of thermodynamics, the entropy of the universe is always increasing but first law of thermodynamics explains that ~~of~~ energy is always conserved in thermodynamic process.

→ Entropy is constantly ~~inducted~~ increasing because every particle and atomic structure accelerates through time and space.

We know,

$$\oint \frac{\delta Q}{T} = \int_{1\,ir}^{2} \frac{\partial Q}{T} + \int_{re\,1}^{2} \frac{\partial Q}{T} < 0$$

$$= \int_{ir\,1}^{2} \frac{\delta Q}{T} + \int_{r\,2}^{1} ds = \int_{ir\,1}^{2} \frac{\delta Q}{T} + (S_1 - S_2) < 0$$

or $\int_{ir\,1}^{2} \frac{\delta Q}{T} < (S_2 - S_1)$

or $\Delta S > \int_{1}^{2} \frac{\delta Q}{T}$

For adiabatic process, $\delta Q = 0$.

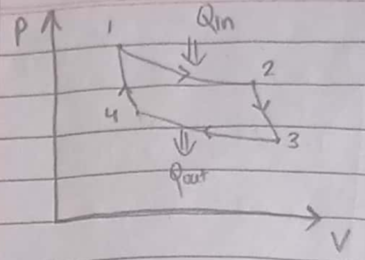
So,

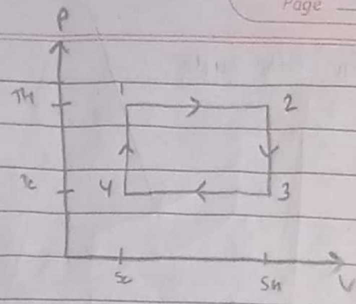
$$\Delta S \geq 0$$

Q.14: Explain Carnot, Reversed Carnot, Otto, Diesel and Brayton cycles with PV and TS diagram.

Soln:

For Carnot cycle.

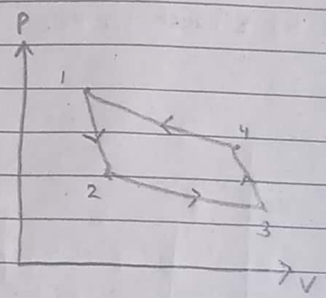




Here,

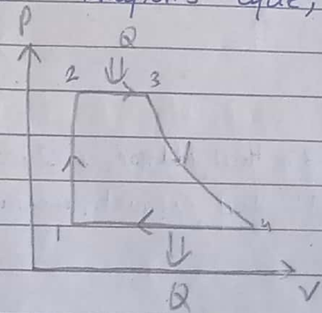
1-2: Rev. isothermal compression.
2-3: Rev. adiabatic compression.
3-4: Rev. isothermal expansion
4-1: Rev. adiabatic expansion

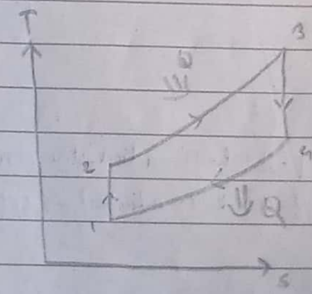
For reversed Carnot cycle:



1-2: Reve. adiabatic expansion
2-3: Rev. isothermal expansion
3-4: Rev. adiabatic compression
4-1: Rev. isothermal compression.

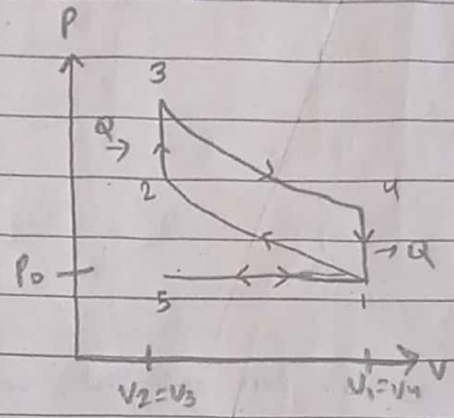
For Brayton's Cycle,





1-2: Rev. adiabatic compression.
2-3: Constant pressure-heat addition.
3-4: Rev. adiabatic expansion
4-1: Constant pressure, heat rejection.

For otto cycle;



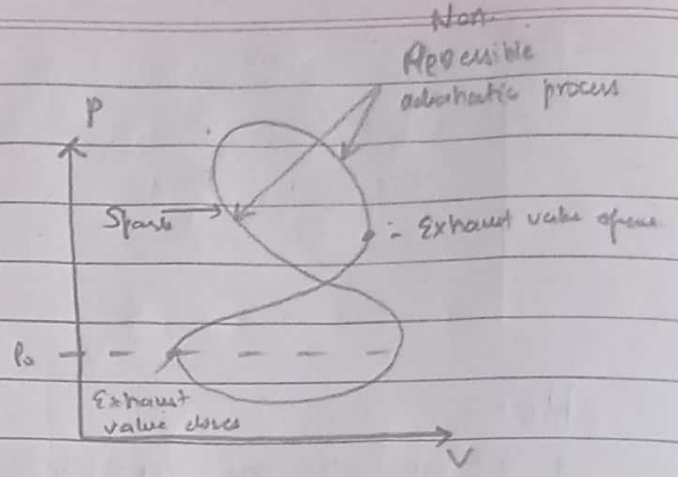


Fig: Ideal otto cycle.

5-1 : Intake stroke

1-2 : Compression stroke, $\Delta T = 0$

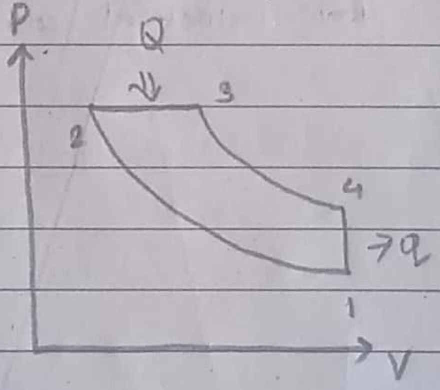
2-3 : Spark i.e. combustion

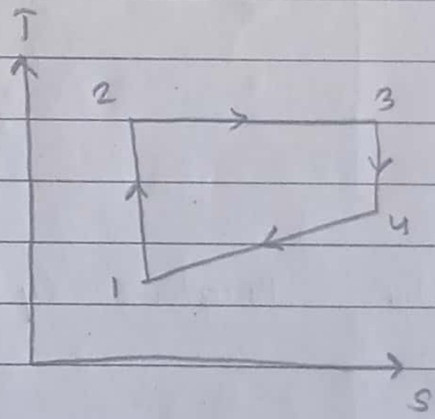
3-4 : Power stroke, expansion.

4-1 : Rejection of heat

1-5 : Exhaust stroke.

For Diesel cycle,





1-2 : Rev. adiabatic compression

2-3 : Heat addition, constant pressure.

3-4 : Rev. adiabatic expansion

4-1 : Heat exhaust, constant volume.