4.66 Discuss with necessary theory the construction and working of a Otto engine.

Construction:

The Otto engine works on the principle of the four-stroke cycle. The four strokes are:

1. Intake stroke: The piston moves downward, creating a vacuum inside the cylinder. The intake valve opens, allowing a mixture of fuel and air to enter the cylinder.
2. Compression stroke: The piston moves upward, compressing the fuel and air mixture. Both the intake and exhaust valves are closed during this stroke.
3. Power stroke: When the fuel and air mixture is compressed, a spark plug ignites the mixture, causing a controlled explosion that drives the piston downward with great force. This downward motion of the piston turns the crankshaft, generating power.
4. Exhaust stroke: The piston moves upward again, and the exhaust valve opens. The upward motion of the piston pushes the exhaust gases out of the cylinder and into the exhaust system.

This answer is taken from web. Most probably Takia Mam didn't reach this topic yet and I don't know either.

4.67 Write short notes on:

(i) Carnot cycle

The Carnot cycle consists of four reversible processes, which are:

1. Isothermal expansion: Heat is added to a gas at a constant temperature, and the gas expands.
2. Adiabatic expansion: The gas expands further without gaining or losing heat.
3. Isothermal compression: Heat is removed from the gas at a constant temperature, and the gas is compressed.
4. Adiabatic compression: The gas is further compressed without gaining or losing heat.

(ii) Carnot's theorem

It states that no engine can be more efficient than a perfectly reversible engine working between the same two temperatures. And the efficiency of all reversible engines, working between the same two temperatures is the same, whatever the working substance.

(iii) Efficiency of carnot's heat engine

In general, the efficiency of an Otto engine is given by the ratio of the net work output to the heat input. The net work output is the difference between the work done by the engine on the piston during the power stroke and the work done by the piston on the engine during the compression stroke. The heat input is the energy released by the combustion of the fuel in the engine's combustion chamber.

(iv) Second law of thermodynamics

It states that the total entropy of an isolated system always increases over time, or remains constant in reversible processes, and can never decrease.
This answer is taken from web. Most probably Takia Mam didn't reach this topic yet and I don't know either.

(v) Zeroth law of thermodynamics

The zeroth law of thermodynamics states that if two bodies A and B are each separately in thermal equilibrium with a third body C, then A and B are also in thermal equilibrium with each other.

(vi) First law of thermodynamics

When a certain amount of heat Q is supplied to a system which does external work W in passing from state 1 to state 2, the amount of heat is equal to sum of the increase in the internal energy of the system and the external work done by the system.

(vii) Internal energy

It is the sum of all the microscopic forms of energy in the system, including the kinetic and potential energies of the particles that make up the system.

(viii) Quassi-static processes

It is a type of thermodynamic process that occurs very slowly and gradually, with the system remaining in thermal and mechanical equilibrium at all times.

(ix) Thermodynamic equillibrium

Thermodynamic equilibrium refers to a state in which a system is in a state of balance and has no net transfer of energy or matter with its surroundings. In thermodynamic equilibrium, all macroscopic properties of the system, such as temperature, pressure, and composition, are uniform and do not change with time.

(x) Reversible and irreversible process

A reversible process is one that can be reversed by an infinitesimal change in some external condition, such as temperature, pressure, or volume, without any net production of entropy. On the other hand, an irreversible process, on the other hand, is one that cannot be reversed without producing entropy.

4.68 A monoatomic idea gas of volume 1 litre and pressure 8 atmosphere undergoes adiabatic expansion until the pressure drops to 1 atmosphere. What is the final volume and how much work is done? Given 1 atm = 10^5 N/m^2.

Given,
$V_1 = 1$ L
$P_1 = 8$ atmosphere
$P_2 = 1$ atmosphere
$V_2 = ?$
$\gamma = 1.67$ (for monoatomic)
We know,

$P_1V_1^{\gamma} = P_2V_2^{\gamma}$
or, $8 \text{ x } 1^{\gamma} = 1 \text{ x } V_2^{\gamma}$
or, $V_2 = \sqrt[\gamma]{8}$
or, $V_2 = 3.47$ L or, $3.47 \text{ x } 10^{-3}$ m^3.

Also,

$$W = \frac{R(T_1 - T_2)}{\gamma - 1}$$

$$\text{or, } W = \frac{R\,x\,T_1 - R\,x\,T_2}{\gamma - 1}$$

$$\text{or, } W = \frac{P_1\,x\,V_1 - P_2\,x\,V_2}{\gamma - 1}$$

$$\text{or, } W = \frac{(8 \times 1 - 1 \times 3.47) \times 1.013 \times 10^{-5} \times 1 \times 10^{-3}}{1.67 - 1}$$

or, $W = \pm 685$ J

4.69 A motor car has a pressure of 3 atmosphere at the room temperature of 27° C. If the tyre suddenly bursts what is the resulting temperature?

Given,
$T_1 = 27^{o}$ C or, $(27 + 273)$ K or, 300 K
$P_1 = 3$ atmosphere
$P_2 = 1$ atmosphere (atmospheric pressure)
$T_2 = ?$
$\gamma = 1.4$ (for atmosphere)
We know,

$$T_1 \times P_1^{\frac{1-\gamma}{\gamma}} = T_2 \times P_2^{\frac{1-\gamma}{\gamma}}$$

$$\text{or, } (27+273) \times 3^{\frac{1-1.4}{1.4}} = T_2 \times 1^{\frac{1-1.4}{1.4}}$$

$$\text{or, } T_2 = (27+273) \times 3^{\frac{1-1.4}{1.4}} \div 1^{\frac{1-1.4}{1.4}}$$

or, $T_2 = 219.1$ K or, -54^{o}C.

4.70 A quantity of air (γ = 1.4) at 27° C is compressed suddenly to [illegible] of its original volume. Find the final temperature.

Given,

T_1 = 27° C or, (27 + 273) K or, 300 K

$V_2 = \frac{V_1}{4}$

T_2 = ?

γ = 1.4

We know,

$$T_1 \times V_1^{\gamma-1} = T_2 \times V_2^{\gamma-1}$$

$$\text{or, } 300 \times V_1^{\gamma-1} = T_2 \times \frac{V_1^{\gamma-1}}{4^{\gamma-1}}$$

$$\text{or, } T_2 = 300 \times 4^{1.4-1}$$

or, T_2 = 522.33 K or, 249.33° C.

4.71 A quantity of air at 27° C and atmospheric pressure is suddenly compressed to $\frac{1}{5}$ of its original volume. Find (I) the final pressure (II) the final temperature.

Given,

T_1 = 27° C or, (27 + 273) K or, 300 K

P_1 = 1 atmosphere

$V_2 = \frac{V_1}{5}$

T_2 = ?

γ = 1.4 (for atmosphere)

We know,

(I) $$P_1 \times V_1^{\gamma} = P_2 \times V_2^{\gamma}$$

$$\text{or, } P_1 \times V_1^{\gamma} = P_2 \times \frac{V_2^{\gamma}}{5^{\gamma}}$$

$$\text{or, } P_2 = 5^{1.4}$$

or, P_2 = 9.51 atmosphere

(II) $$T_1 \times V_1^{\gamma-1} = T_2 \times V_2^{\gamma-1}$$

$$\text{or, } 300 \times V_1^{\gamma-1} = T_2 \times \frac{V_1^{\gamma-1}}{5^{\gamma-1}}$$

$$\text{or, } T_2 = 300 \times 5^{1.4-1}$$

or, T_2 = 571.1 K or, 298.1° C.

4.72 A certain mass of an ideal gas at 27° C temperature and 8 atmospheric pressure, is expanded suddenly to 4 times of its volume. Find final pressure and final temperature. (Given γ = 1.5)

Given,

T_1 = 27° C or, (27 + 273) K or, 300 K

P_1 = 8 atmosphere

$V_2 = V_1 \times 4$
$T_2 = ?$
$\gamma = 1.5$
We know,

(I) $P_1 \times V_1^{\gamma} = P_2 \times V_2^{\gamma}$

or, $P_1 \times V_1^{\gamma} = P_2 \times V_2^{\gamma} \times 4^{\gamma}$

or, $P_2 = \dfrac{1}{4^{1.5}}$

or, $P_2 = 0.125$ or, $\dfrac{1}{8}$ atmosphere

(II) $T_1 \times V_1^{\gamma-1} = T_2 \times V_2^{\gamma-1}$

or, $300 \times V_1^{\gamma-1} = T_2 \times V_1^{\gamma-1} \times 4^{\gamma-1}$

or, $T_2 = \dfrac{300}{4^{1.5-1}}$

or, $T_2 = 150$ K.

4.73 A carnot engine has an efficiency of 30% when the temperature of the sink is 27°C. Find the temperature of the source.

Given,
Source temperature, $T_1 = ?$
Sink temperature, $T_2 = 27°C$ or, 300K.
Efficiency, $\eta = 30\%$ or, 0.3
We know,

$\eta = 1 - \dfrac{T_2}{T_1}$

or, $T_1 = \dfrac{T_2}{1-\eta}$

or, $T_1 = \dfrac{300}{1-0.3}$

or, $T_1 = 428.57\,K$ or, 155.57°C

4.74 The temperature of 5 kg of air is raised by 1°C at constant volume. Calculate the increase in its internal energy. (Given $C_p = 999\,J\,kg^{-1}K^{-1}$, $\gamma = \dfrac{5}{3}$)

Given,
$C_p = 999\,J\,kg^{-1}K^{-1}$, $\gamma = \dfrac{5}{3}$

As, here volume is constant, there will be no work (dw)
so, $dQ = dU$

we know,
$C_p = \dfrac{Q}{m.\Delta T}$

or, $Q = C_p . m . \delta . T$

or, $Q = 999 \times 5 \times \frac{5}{3} \times (273+1)$

or, Q = dU = 2281050 J

I'm not sure about the answer of this problem and my implementation. Feel free to reach me out to help me to solve it. Sincerely appreciate it!

4.75 If the temperature of the sink is 20°C and that of the source 250°C, calculate the efficiency of the carnot's engine.

Given,
Source temperature, T_1 = 250ºC or, 523 K
Sink temperature, T_2 = 20ºC or, 293 K.
Efficiency, η = ?
We know,

$$\eta = 1 - \frac{T_2}{T_1}$$

or, $\eta = 1 - \frac{293}{523}$

or, $T_1 = 303 K$, or, 44%

4.76 Initial pressure of an ideal gas at 30ºC is 'P'. Calculate the rise in temperature at which the pressure suddenly increases to 10 times the original pressure. (Given γ= 1.4)

Given,
$\eta = 0.44$
$P_2 = 10 P_1$,
$\gamma = 1.4$
We know,

$$T_2 = T_{1.} \left(\frac{P_2}{P_1}\right)^{\gamma - 1/\gamma} = 303 \times 10^{\frac{0.4}{1.4}} = 585 K$$

So, rise in temperature is 585-303 = 282 Kj

4.77 Dry air at N.T.P. (normal temperature and pressure) is compressed adiabatically to one-third of its original volume. Calculate the resulting pressure. Given that the ration C_p / C_v of air is 1.40.

Given,
P_1 = 1 atmosphere
$V_2 = \frac{V_1}{3}$
γ = 1.4 (for N.T.P)
We know,

$$P_1 \times V_1^\gamma = P_2 \times V_2^\gamma$$

or, $P_1 \times V_1^\gamma = P_2 \times \frac{V_2^\gamma}{3^\gamma}$

or, $P_2 = 3^{1.4}$

or, P_2 = 4.66 atmosphere

4.78 A Carnot's engine whose temperature of the source is 400K takes 500 calories of heat at this temperature and rejects 400 calories of heat to the sink. What is the temperature of the sink? Calculate the efficiency of the engine.

Given,
Source temperature, T_1 = 400 K
Source energy transfer Q_1 = 500 cal
Sink temperature, T_2 = ?.
Source energy transfer Q_2 = 400 cal
we know,

$$\eta = 0.2$$

or, $\eta = 1 - \frac{T_2}{T_1}$

or, $\eta = 1 - \frac{320}{400}$

Again Given,
Source temperature, T_1 = 400 K
Sink temperature, T_2 = 320 K.
Efficiency, η = ?
We know,

$$\frac{Q_1}{Q_2} = \frac{T_1}{T_2}$$

or, $T_2 = \frac{400 \times 400}{500}$

or, $T_2 = 320\,K$ or, 20%

4.79 A Carnot's engine is operated between two reservoirs of 500K and 400K. If the engine receives 2000 calories of heat from the source in each cycle, calculate (a) the amount of heat rejected to the sink in each cycle, (b) the efficiency of the engine and (c) the work done by the engine in each cycle in (i) Joule (ii) Kilo-Watt hours.

(a) Given,
Source temperature, T_1 = 500 K
Source energy transfer Q_1 = 2000 cal
Sink temperature, T_2 = 400 K
Source energy transfer Q_2 = ?
we know,

$$T_2 = 1600\,K$$

or, $\frac{Q_1}{Q_2} = \frac{T_1}{T_2}$

or, $Q_2 = \frac{2000 \times 400}{500}$

(b) Again Given,
Source temperature, T_1 = 500 K
Sink temperature, T_2 = 400 K.
Efficiency, η = ?

We know,

$$\eta = 0.2$$

or, $\eta = 1 - \frac{T_2}{T_1}$

or, $\eta = 1 - \frac{400}{500}$ or, 20%

(c) Again given,
Source energy transfer Q_1 = 2000 cal or, 8400 J (2000 x 4.2)
Source energy transfer Q_2 = 1600 cal or, 6720 J
$W = Q_1 - Q_2$
or, $W = 8400 - 6720$
or, $W = 1680\ J$ or, $\frac{1680}{3.6 \times 10^6}$ kWh or, 0.000467 kWh

Answer is different from our text book right? So here is a Reference,
https://www.assignmentexpert.com/homework-answers/physics/molecular-physics-thermodynamics/question-130393
Feel free to correct me if I'm wrong!

4.80 A Carnot's engine takes in 1000 kilocalories of heat a reservoir at 627° C and exhausts it to a sink at 27° C. (a) What is its efficiency, (b) How much work does it perform? Express it in (i) ergs (ii) kilo-watt hours (iii) electron volts.

(a) Given,
Source temperature, T_1 = 900 K
Sink temperature, T_2 = 300 K.
Efficiency, η = ?
We know,

$$\eta = 0.667$$

or, $\eta = 1 - \frac{T_2}{T_1}$

or, $\eta = 1 - \frac{300}{900}$ or, 66.67%

(b) Again given,
Source energy transfer Q_1 = 1000 kilocalories
Efficiency, η = 0.667
So, work done = 1000 x 0.667 = 667 kilocalories (2.791e+10 ergs)

I can't solve it, it seems. Help me if possible please. Sincerely appreciate it!
https://t.me/SharafatKarim