Question sheet 4 on Thermodynamics- Power Plant Engineering

Q1. A supersonic aircraft if flying at an altitude of 3km with a constant flight speed of 2000km/h. The aircraft passes over a ground observation post. Find the time taken to hear the sound waves from the aircraft at the observation post after it has past directly over it. Assume the average temperature of atmospheric air at the observation post to be 27 °C.

ANS:-6.75 sec

Q2. Air at 110 KPa ,90 °C, with a velocity of 180m/s is to be expanded isentropically through a convergent –divergent nozzle ,until its Mach number becomes 1.5 Kg/s. The mass flow rate of air is 0.15 kg/s. Determine the final pressure and cross –sectional area at the nozzle exit.

ANS:-

PRESSUERE: -34.9KPa

CROSS-SECTIONAL AREA:-6.636 =cm^2

Q3. Air at 28 °C and 700 KPa enters a nozzle with a velocity of 80 m/s. The nozzle has inlet area of 10cm^2 .The air leaves the nozzle of a pressure of 250KPa.Determine

(a)mass flow rate of air through the nozzle, and

(b)velocity at the exit of nozzle, assuming one dimensional isentropic flow.

ANS:-

MASS FLOW RATE:- 0.648 Kg/s

VELOCITY:- 400.72 m/s

Q4. Air at 8.6 bar ,and 190 °C expands at a rate of 4.5 kg/s through a convergent-divergent nozzle to an atmospheric pressure of 1.013 bar .Assuming that the inlet velocity is negligible. Calculate the throat and exit cross-section areas of the nozzle.

ANS:-

THROAT AREA:-2788.8 mm^2

EXIT AREA:-4903mm^2

Q5. A four- stroke, four –cylinder petrol engine of 250 –mm bore and 375 –mm stroke works on Otto cycle. The clearance volume is 0.01052 m^3 .The initial pressure and temperature are 1 bar and 47 °C .If the maximum pressure is limited to 25 bar, Find the following:

(a)Air standard efficiency of the cycle.

(b)The mean effective pressure.

ANS:-

AIR STANDARD EFFICIENCY: -56.5%

THE MEAN EFFECTIVE PRESSURE: -1.346 bar.

Q6. In an SI engine working on an ideal Otto cycle, the compression ratio is 5.5. The pressure and temperature at the beginning of compression are 1 bar and 27 °C, respectively. The peak pressure

is 30 bar. Determine the pressure, temperature at the salient points, the air standard efficiency, and mean effective pressure.

Assume ratio of specific heat `to be 1.4 for air.

ANS:-

PRESSURE:-

Pa=10.877bar

Ta=320.28℃

Pb=30 bar

Tb=1363.33 ℃

Pc=2.758 bar

Tc=554.42℃

Air standard efficiency=49.4%

Mean effective pressure=5.24 bar

Q7. An engine working on Otto cycle has a total volume of 0.45m^3 ,pressure 1 bar and temperature 27 °C at the beginning of the compression stroke. At the end of compression stroke, the pressure is 11 bar and 210 KJ of heat is added at constant volume. Calculate

(a)the pressure, temperature and volume at the salient points in the cycle.

(b)Percentage clearance volume.

(c)net work done per cycle.

(d)the ideal power developed by the engine if the number of working cycles per minute is 210.

ANS:-

Va=0.081$\boldsymbol{m^3}$

Ta=322.68 ℃

Pb=21.4 bar

Tb=886℃

Vb=0.081$\boldsymbol{mm^3}$

Pc=1.94 bar

Vc=0.45$\boldsymbol{mm^3}$

Tc=544k

Percentage clearance volume=2.19%

Net work done per cycle=104.2 KJ

Ideal power developed=364.68 KW

Q8. Prove that the compression ratio corresponding to maximum work in the otto cycle between the upper and lower limits of absolute temperature $T_3 \quad and \quad T_1$ respectively is given by

$$r = \left(\frac{T_3}{T_3}\right)^{\frac{1}{2(\gamma-1)}}$$

(b)Calculate the air standard efficiency of cycle, when it develops maximum work and operates between 300 K and 1200 K as minimum and maximum temperature s, respectively with working fluid as air .

(c)Calculate the change in efficiency , if helium is used in Otto cycle ?The cycle operates between same temperature limits for maximum work output.
For air $\gamma = 1.4$

For helium take C_p=5.22 Kj/kg , C_v=3.13KJ/kg.K

ANS:-

AIR STANDARD EFFICIENCY =50 %

Q9.An engine works on a diesel cycle with an inlet pressure and temperature of 1 bar and 17 ℃ .The pressure at the end of adiabatic compression is 35 bar. The ratio of expansion i.e. after constant pressure heat condition is 5.Calculate the heat addition ,heat rejection and efficiency of the cycle.

ANS:-

HEAT ADDITION: - 1233.9KJ/Kg

HEAT REJECTION =556.67KJ/Kg

EFFICIENCY =54.88%

Q10.Consider an ideal diesel cycle. At the beginning of the compression process , the cylinder volume is 1500 cm^3 and at the end of heat addition process , it is 150 cm^3 .The compression ratio is 15.Air is at 101KPa and 20 ℃ at the beginning of compression process. Calculate

(a)Pressure at the beginning of heat rejection process.

(b)Net work per cycle in KJ.

(c)The mean effective pressure of the cycle.

ANS:-

Pressure at the beginning of heat rejection process:-1.78 bar

Net work per cycle in KJ:-0.38 KJ

The mean effective pressure of the cycle:-2.7 bar

Q11.The pressure ratio and maximum temperature of a Brayton cycle are 5:1 and 923 K, respectively. Air enters the compressed at 1 bar and 298 K .Calculate for 1 kg of air flow, the compressor work, turbine work and efficiency of cycle.

ANS:-

COMPRESSOR WORK:-174.87KJ/Kg

TURBINE WORK:-341.94 KJ/Kg

THERMAL EFFICIENCY:-36.86%