**NED UNIVERSITY OF ENGINEERING & TECHNOLOGY**
**FOURTH YEAR FALL TERM (MECHANICAL ENGINEERING)**
**EXAMINATION 2011**
**BATCH 2007-08**

**Time: 3 Hours** | **Dated: 22-11-2011**
**Max. Marks: 75/80**

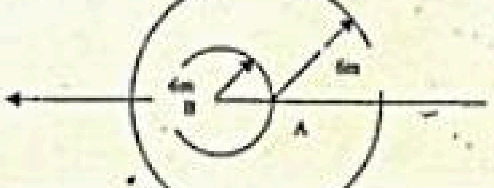
## GAS DYNAMICS- ME-405

**Instructions :**
1) Attempt any five questions in all.
2) Assume missing data accordingly
3) Draw neat sketches wherever required.

---

**Question 1**

a) A particle is moving in air at sea level where the temperature is 15 °C. The two disturbance spheres created by the particle at point A and B are shown in the diagram below. Determine the Mach number and the velocity of the particle [08]




b) Show that, for a perfect gas, the fractional change in pressure across an infinitesimal pressure pulse is given by the equation $dp/p = k\, dV/a$ and the fractional change in the temperature is given by the equation $dT/T = (\gamma-1)\, dV/a$ [07]

**Question 2**

a) At a point upstream of the throat in a converging-diverging nozzle, the velocity, temperature and pressure are 172 m/s, 22 °C and 200 kPa, respectively. If the nozzle, operating at its design condition, has an exit area of 0.01 m$^2$ and discharges to the atmosphere at 100 kPa, show the process on a T-s diagram and determine the mass flow rate and nozzle throat area. [08]

b) Describe choking process in isentropic variable area flow passage and derive the following equation

$$\frac{A}{A^*} = \frac{1}{M}\left[\frac{2}{\gamma+1}\left(1+\frac{\gamma-1}{2}M^2\right)\right]^{\frac{(\gamma+1)}{2(\gamma-1)}}$$ [07]

**Question 3**

a) At the discharge of an air-conditioning duct it is desirable to reduce the cross-sectional area of the duct. The cross-sectional the smaller duct is 0.02m$^2$. At inlet of the larger duct the pressure, temperature and velocity are 150 kPa, 327 K and 71 m/s, respectively. If the flow throughout the duct is isentropic and if it discharges to an ambient pressure of 100 kPa, determine the mass flow rate. [07]

b) At a point upstream of the throat in a converging-diverging nozzle, the pressure, temperature and velocity of the air are 200 kPa, 400 K and 200 m/s, respectively. The exit and throat cross-sectional areas are 0.002 m$^2$ and 0.001 m$^2$, respectively. Determine the Mach number, temperature and pressure at the exit plane. Also find the back pressure and mass flow rate. The nozzle is operating at its design condition. [08]

**Question 4**

a) A converging-diverging nozzle is fed with air from large reservoir, where the temperature and pressure are 500 K and 450 kPa, respectively. The ratio of the exit to the throat areas is 1.25. The nozzle discharges to the atmosphere with a pressure of 100 kPa. Determine the Mach number, pressure and temperature at the exit plane, and also calculate the mass flow rate. [08]

b) Air with a stagnation pressure of 650 kPa and stagnation temperature of 350 K is flowing isentropically through a converging nozzle. At a section within the nozzle, where the cross-sectional area is 0.0026 m$^2$, the Mach number is 0.5. The nozzle discharges to a back pressure of 270 kPa. Determine the Mach number, pressure, temperature and cross-sectional area at the exit plane. Also find the mass flow rate. [07]

**Question 5**

a) An insulated duct with cross-sectional area of 0.001 m$^2$ is fed with air through an isentropic converging-diverging nozzle. At the inlet of the duct, the pressure, temperature and Mach number are 150 kPa, 300 K, 1.5 respectively. If the flow is choked at the exit of the duct, calculate the exit temperature, the net force of the fluid on the pipe and the entropy change. [08]

b) Describe with the help of diagrams the performance of an adiabatic duct fed by an isentropic converging nozzle and explain the choking in Fanno line flow. [07]



**Question 6**

a) Air flows isothermally through a duct with a cross-sectional area of 0.025 m$^2$. At inlet section the pressure, temperature, and velocity are 200 kPa, 300K, and 100 m/s, respectively. At exit section the pressure is 100 kPa. Determine the mass flow rate, the properties at exit, and the frictional force acting on the duct. [08]

b) Why does stagnation temperature change along the flow in an isothermal flow, explain with the help of diagram. Obtain the following equation for an isothermal flow

$$\frac{T_0}{T_0^*} = \frac{2\gamma}{3\gamma-1}\left(1+\frac{\gamma-1}{2}M^2\right)$$ [07]

**Question 7**

a) Air flows with a rate of 10 kg/s through a duct with a cross-sectional area of 0.03 m$^2$. At the duct inlet, the temperature and pressure are 350 K and 150 kPa, respectively. At the exit section the flow is choked. Determine the rate of heat transfer, the entropy change and the change in the stagnation pressure. Assume frictionless flow. [08]

b) For Rayleigh flow obtain the values of Mach numbers at two limiting conditions of $h_{max}$ and $S_{max}$. Also explain choking in the flow with heat transfer. [07]

**Question 8**

a) A uniform supersonic air flow traveling at Mach number of 3.0 passes over a wedge which deflects the flow by 18°. If the pressure and temperature of the uniform flow are 30 kPa and 5 °C, respectively, determine the shock-wave angle, Mach number, pressure and temperature downstream of the oblique shock wave. [07]

b) A uniform supersonic air flow traveling at a Mach no. of 2.0 passes over a concave corner. An oblique shock wave, which makes an angle of 40° with the flow direction, is attached to the corner under the given conditions. If the pressure and temperature in the uniform flow are 40 kPa and 253 K, respectively, determine the pressure and temperature behind

Q6 a) Derive the equation describing Fanno flow and show two Fanno curves of different mass fluxes, G, on p-v and h-s diagrams. [Marks 06]

b) An insulated duct with a cross-sectional area of 0.001 $m^2$ is fed with air through an isentropic converging-diverging nozzle. At the inlet of the duct, the pressure, temperature and Mach number are 150 kPa, 300 K and 1.5, respectively. If the flow is choked at the exit of the duct, calculate the exit temperature, the net force of the fluid on the pipe and the entropy change. [09]

Q7 a) For a compressible flow in a duct of constant area with heat transfer, determine the following equation for the stagnation pressure ratio

$$\frac{P_o}{P_o^*} = \frac{1+\gamma}{1+\gamma M^2}\left(\frac{2+(\lambda-1)M^2}{(\gamma+1)}\right)^{\frac{\gamma}{(\lambda-1)}} \quad [06]$$

b) Air flows with negligible friction in a constant area pipe. At the inlet the velocity of air is 732 m/s, temperature is 60 °C and pressure is 135 kPa. Heat is added to the gas between the inlet and exit such that the Mach number at the exit is 1.2. Determine

(i) Flow properties at the exit (ii) the amount of heat transfer per unit mass (iii) change in stagnation pressure (iv) change in entropy.(v) sketch the process on T-s diagram. [09]

Q8 a) Explain how the analysis for a normal shock wave can be employed for the analysis of an oblique shock wave. [05]

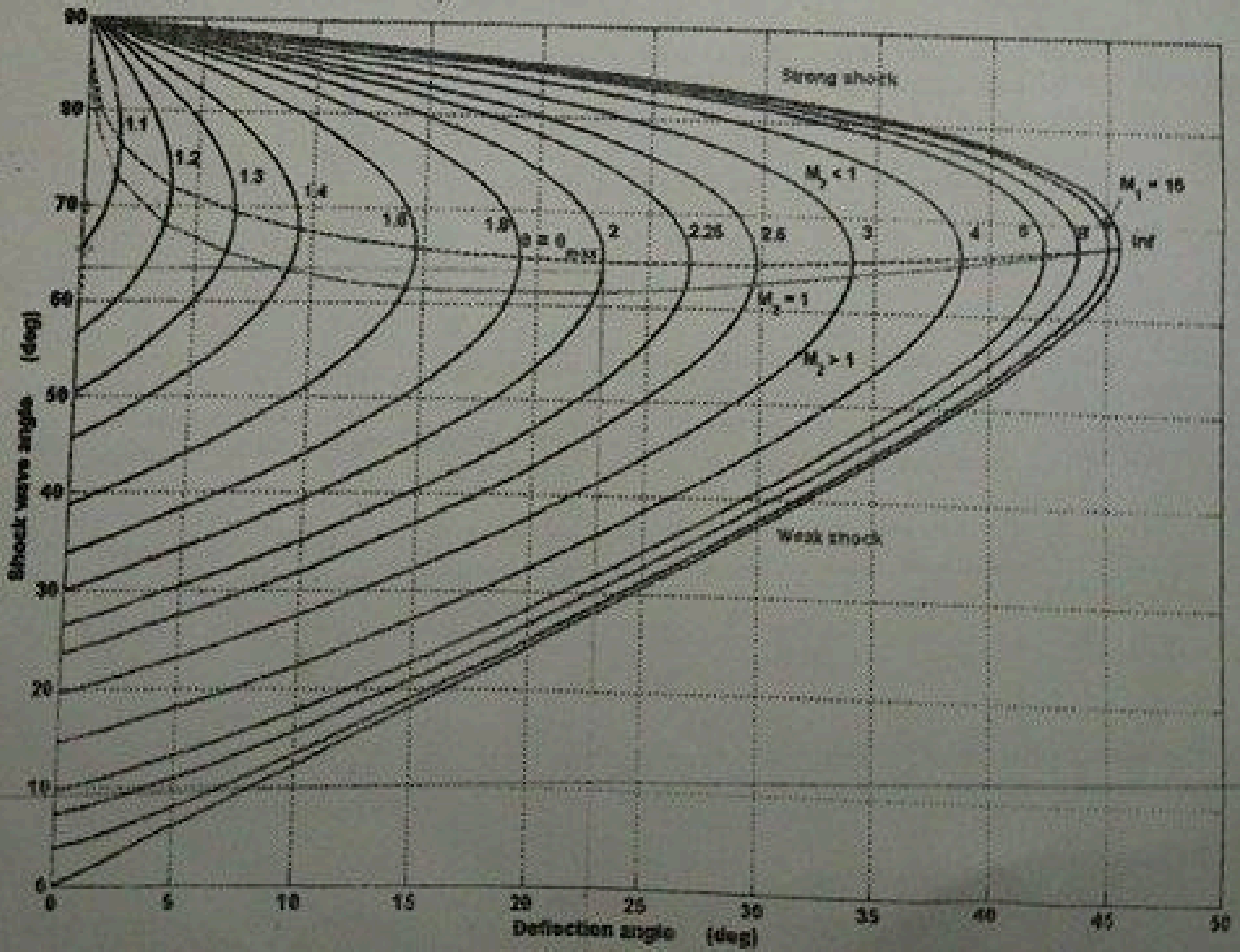
b) A uniform supersonic air flow traveling at a Mach number of 2 passes over a concave corner. An oblique shockwave, which makes an angle of 40° with the flow direction, is attached to the corner under the given conditions. If the pressure and temperature in the uniform flow are 40 kPa and 253 K, respectively, determine the pressure and temperature behind the wave, downstream Mach number and the deflection angle. Also find the maximum allowable deflection angle before the oblique shock wave detaches itself from the corner. [10]

**Relations:**

$$\sin^2\theta_{max} = \frac{1}{\gamma M_x^2}\left[\frac{\gamma+1}{4}M_x^2 - 1 + \sqrt{\left[(\gamma+1)\left(1+\frac{\gamma-1}{2}M_x^2+\frac{\gamma+1}{16}M_x^4\right)\right]}\right]$$

$$\sin^2\theta_s = \frac{1}{\gamma M_x^2}\left[\frac{\gamma+1}{4}M_x^2 - \frac{3-\gamma}{4} + \sqrt{\left[(\gamma+1)\left(\frac{9+\gamma}{16}+\frac{3-\gamma}{8}M_x^2+\frac{\gamma+1}{16}M_x^4\right)\right]}\right]$$

$$\cot\delta = \left(\frac{\gamma+1}{2}\frac{M_x^2}{M_x^2\sin^2\theta - 1} - 1\right)\tan\theta$$



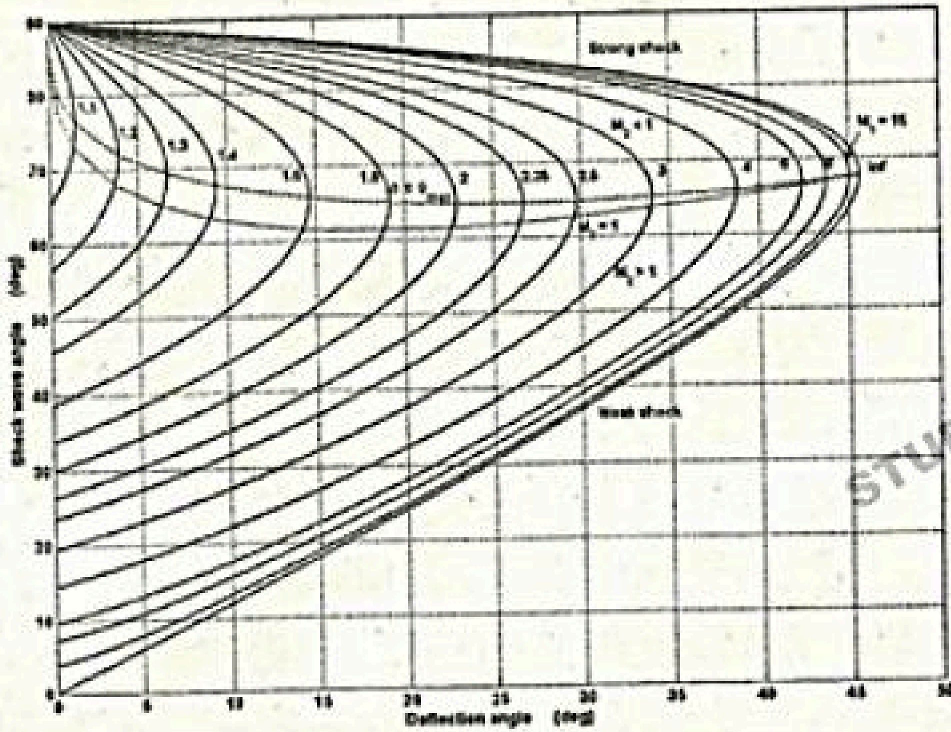
the wave, the downstream Mach number and the deflection angle. Also find the maximum allowable deflection angle before the oblique shock wave detaches from the concave corner. [08]

Relations:

$$\sin^2\theta_{max} = \frac{1}{\gamma M_s^2}\left[\frac{\gamma+1}{4}M_s^2 - 1 + \sqrt{\left[(\gamma+1)\left(1+\frac{\gamma-1}{2}M_s^2+\frac{\gamma+1}{16}M_s^4\right)\right]}\right]$$

$$\sin^2\theta_s = \frac{1}{\gamma M_s^2}\left[\frac{\gamma+1}{4}M_s^2 - \frac{3-\gamma}{4} + \sqrt{\left[(\gamma+1)\left(\frac{9+\gamma}{16}+\frac{3-\gamma}{8}M_s^2+\frac{\gamma+1}{16}M_s^4\right)\right]}\right]$$

$$\cot\delta = \left(\frac{\gamma+1}{2}\frac{M_s^2}{M_s^2\sin\theta - 1} - 1\right)\tan\theta$$



Q6 a) Air enters at a Mach number of 3 in duct of constant cross-section area of $0.02 m^2$. The inlet air temperature is 300 K and pressure is 200 kPa. A normal shock wave forms downstream where the Mach number is 1.8. Determine, flow properties at the exit where the Mach number is 0.92. Also estimate the amount of heat transfer rate, and entropy change, sketch the process on a T-s diagram. [08]

b) For Rayleigh flow obtain the values of Mach numbers at two limiting conditions of $h_{max}$ and $S_{max}$. Also explain choking process in Rayleigh flow. [07]

Q7 a) A supersonic jet engine receives air at a Mach number of 3. Determine the loss of stagnation pressure

I. If one normal shock wave forms at engine inlet.
II. If a spike type diffuser is present at the inlet and one oblique shock and one normal shock are formed.
III. If two oblique and one normal shock waves are formed [08]

Assume that each oblique shock turns the flow by 5 degrees.

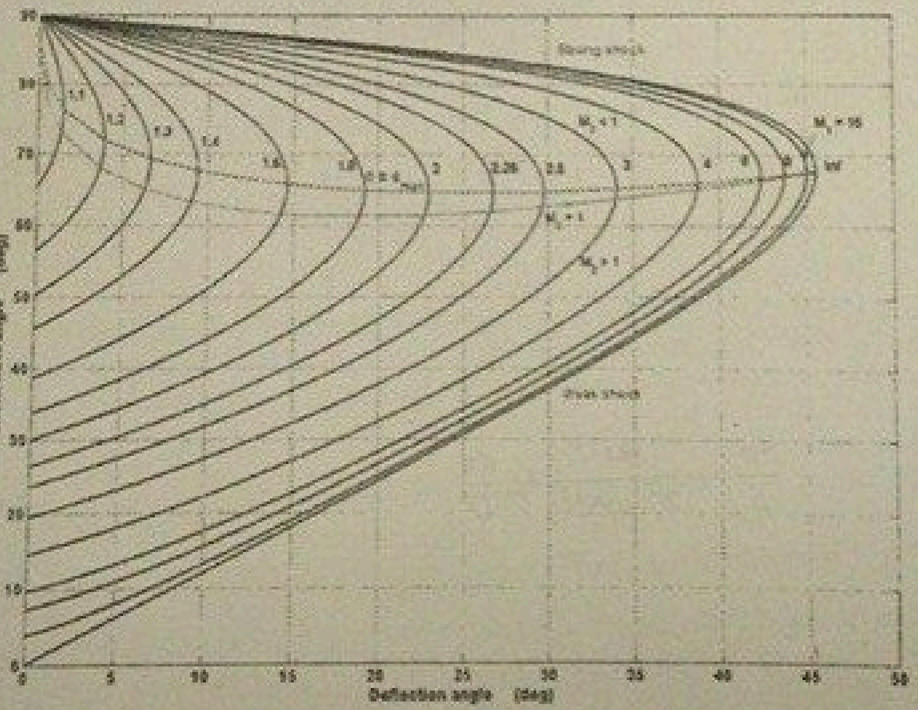
b) A uniform supersonic air flow traveling at Mach number of 2.5 passes over a wedge which deflects the flow by 15°. If the pressure and temperature of the uniform flow are 40 kPa and -10 °C, respectively, determine the oblique shock angle, Mach number, pressure and temperature downstream of the oblique shock wave. Also find the deflection angle for which the downstream Mach number is unity. [07]

**Useful relations:**

$$\sin^2\theta_{max} = \frac{1}{\gamma M_1^2}\left[\frac{\gamma+1}{4}M_1^2 - 1 + \sqrt{(\gamma+1)\left(1+\frac{\gamma-1}{2}M_1^2+\frac{\gamma+1}{16}M_1^4\right)}\right]$$

$$\sin^2\theta_s = \frac{1}{\gamma M_1^2}\left[\frac{\gamma+1}{4}M_1^2 - \frac{3-\gamma}{4} + \sqrt{(\gamma+1)\left(\frac{9+\gamma}{16}+\frac{3-\gamma}{8}M_1^2+\frac{\gamma+1}{16}M_1^4\right)}\right]$$

$$\cot\delta = \left(\frac{\gamma+1}{2}\frac{M_1^2}{M_1^2\sin^2\theta-1}-1\right)\tan\theta$$



# NED UNIVERSITY OF ENGINEERING & TECHNOLOGY

## FINAL YEAR FALL TERM (MECHANICAL ENGINEERING)

## EXAMINATION 2013

## BATCH 2009-10 & PREVIOUS BATCHES

Time: 3 Hours

**Dated: 19-11-2013**
**Max. Marks: 75**

## GAS DYNAMICS- ME-405

**Instructions:**

1) Attempt any five questions in all
2) Assume missing data accordingly
3) Draw neat sketches wherever required
4) Gas dynamics charts and tables can be consulted

---

Q1 a) A supersonic aircraft flies at an altitude of 3000 m. Determine its velocity if the sound is heard 5 seconds after its passage over the head of an observer. Assume that the air has an average temperature of 15 °C. [07]

b) An aircraft at an altitude of 2500 m passes over the head of an observer on the ground. The Mach number of the aircraft is 1.8. Assuming an isothermal atmosphere with a temperature of -5 °C, find the speed of the aircraft. How long after it passes directly overhead does its Mach cone pass a point on the ground? [08]

Q2 a) Air flows steadily and isentropically into an aircraft inlet at a mass flow rate of 50 kg/s. at a section where the cross sectional area is 0.5 $m^2$, the temperature and pressure are 323 K and 20 kPa, respectively. Determine the velocity, pressure and cross sectional area at a downstream section where the temperature is 350 K. Sketch the flow passage and show the process on T-s diagram. [07]

b) A supersonic nozzle has throat and exit cross-sectional areas of 0.09$m^2$ and 0.15$m^2$ respectively. The mass flow rate of the air is 14 kg/s. the supply pressure and temperature at the nozzle inlet where the velocity is negligible are 68 kPa and 40 °C, respectively. Assuming steady, one dimensional isentropic flow determine the fluid properties at the throat and exit, and show the process on T-s diagram. [08]

Q3 a) Air with a Mach number of 2, a pressure of 150 kPa and a temperature of 350 K enters a diverging channel. If ratio of the exit to inlet cross sectional area is 3, determine the back pressure which is necessary to produce a normal shock wave in the channel with a cross sectional area equal to twice the inlet cross sectional area. Assume steady, one dimensional, isentropic flow except through normal shock wave. [08]

b) Obtain the following relation from the Fanno line and Rayleigh line equation for normal shock wave

$$M_y = \sqrt{\left(\frac{(\gamma-1)M_x^2+2}{2\gamma M_x^2-(\gamma-1)}\right)}$$ [07]

Q4 a) Air at a stagnation temperature of 400K and stagnation pressure of 300 kPa is supplied to a constant area insulated duct through an isentropic converging nozzle. The duct has a diameter of 0.04m and length of 8.5m. and it discharges to the atmosphere with a pressure of 100 kPa. Assume a friction factor of 0.001

I. Determine the inlet and exit Mach numbers
II. Determine the pressure and temperature at the exit of the duct
III. Determine the mass flow rate
IV. Show the process on T-s diagram

[08]

b) For a Fanno line flow prove that the non-dimensional temperature ratio is given by

$$\frac{T}{T^*} = \frac{\gamma+1}{2\left(1+\frac{1}{2}(\gamma-1)M^2\right)}$$ [07]

Q5 a) a) Air flows isothermally through duct with cross sectional area of 0.025 $m^2$. At section 1 the pressure, temperature and velocity are 200 kPa, 300 K, and 100 m/s, respectively. At section 2, the pressure is 100 kPa. Determine the mass flow rate, properties at section 2 and frictional force acting on the duct walls. Also find the heat transfer rate. [08]

b) Describe isothermal flow and give some examples from real life. Obtain the following equation for an isothermal flow

$$\frac{dp}{p} = -\frac{\gamma M^2}{2(1-\gamma M^2)} 4f \frac{dx}{D}$$ [07]

P.T

# NED UNIVERSITY OF ENGINEERING & TECHNOLOGY
## FINAL YEAR FALL TERM (MECHANICAL ENGINEERING)
## EXAMINATION 2012
## BATCH 2008-09

Time: 3 Hours

Dated: 22-11-2012
Max. Marks: 75/80

## GAS DYNAMICS- ME-405

**Instructions :**

1) Attempt any five questions in all.
2) Assume missing data accordingly
3) Draw neat sketches wherever required.
4) Gas tables & chart can be consulted.

**Q1** a) A supersonic aircraft flies at an altitude of 3500 m. An observer on the ground hears the noise generated by the aircraft, which is 3000 m away horizontally, after 11 seconds. Assuming that the atmosphere is isothermal, determine

I. The Mach number of the aircraft
II. Velocity of the aircraft
III. The distance traveled before the observer hear the noise
IV. The temperature of the isothermal atmosphere [07]

b) A supersonic aircraft flies at a constant altitude of 2250 m. Determine its velocity if the sound is heard 5 seconds after the passage over the head of an observer. Assume that air has an average temperature of 10 °C. [08]

**Q2** a) An isentropic converging-diverging nozzle is fed with air from a large reservoir where the temperature and pressure are 500 K and 900 kPa respectively. The ratio of the exit to the throat cross-sectional area is 1.25. The nozzle discharges to the atmosphere with a pressure of 100 kPa. Determine the Mach number, temperature, pressure and mass flux at the exit plane. [08]

b) For isentropic flow through a variable area passage obtain the following equation and explain its significance

$$\frac{\dot{m}\sqrt{RT_o}}{Ap_o} = \sqrt{(\lambda)}M\left(1+\frac{\gamma-1}{2}M^2\right)^{\frac{-(\gamma+1)}{[2(\gamma-1)]}} \qquad [07]$$

**Q3** a) Air flows from a large tank where the pressure and temperature are 600 kPa and 800K, respectively, through a converging nozzle with an exit area of 0.005m$^2$ and discharges to the atmosphere with a pressure of 100 kPa. The flow is isentropic throughout the nozzle. Determine the Mach number, temperature, pressure and velocity at the exit section, and also calculate the mass flow rate. [07]

b) A converging nozzle discharging air at 47.8 kg/s has an exit cross-sectional area of 0.1m$^2$. The stagnation pressure and stagnation temperature of the air are 240 kPa and 20 °C, respectively. Calculate the back pressure into which the nozzle is discharging. The flow is isentropic throughout. [08]

**Q 4** a) For a flow with a normal shock wave obtain the following equation

$$M_y = \sqrt{\left(\frac{(\gamma-1)M_x^2+2}{2\gamma M_x^2-(\gamma-1)}\right)} \qquad [07]$$

b) An aircraft engine employs a subsonic inlet diffuser of area ratio 3.5. Free stream air at a total pressure and temperature of 1 bar and 600 K respectively, approaches the diffuser with a Mach number of 2.2. A shock wave stands just outside the diffuser inlet. Determine the Mach number, pressure and temperature of the air at the exit of the diffuser. Also find the loss in stagnation pressure of air. [08]

**Q5** a) Describe choking effects in an isothermal flow. Explain how the pressure, temperature, stagnation pressure, stagnation temperature and Mach number are affected in a duct with isothermal flow, when the initial Mach number is

$(i) M < \frac{1}{\sqrt{\gamma}}$ and $(ii) M > \frac{1}{\sqrt{\gamma}}$ [Marks 06]

b) Air enters a constant area duct at a velocity of 600m/s, a pressure of 100 kPa and a temperature of 400K. The flow in the duct is isothermal. The duct has a diameter of 0.04 m and an average friction factor of 0.002, determine

I. The mass flow rate
II. The Mach number, pressure and temperature at the exit of the duct
III. The force exerted by air on the duct walls
IV. Rate of heat transfer [Marks 09]

P.T.O