Conventional Paper-I-2012

1.a. For an isentropic expansion of a gas with $c_p = a + kT,\ c_v = b + kT$ and $c_p - c_v = R$, show that $T^b v^{a-b} e^{kT} = \text{constant}$. [5]

1.b. A small flexible bag contains 0.1kg ammonia at -10ºC and 3bar. The bag material is such that the pressure inside varies linearly with volume. The bag is left in open space where the incident solar radiation is 75W. The heat energy lost to the ground and surrounding air from bag is at the rate of 25W. After a while, it is found that the bag is heated to 30ºC at which time the pressure of ammonia is 10bar. Estimate (i) the amount of heat energy infiltrated into the bag and (ii) the elapsed time. [10]

a. Properties of ammonia:
   Compressed liquid ammonia at $-10^\circ C$, 3bar
   Specific volume of saturated liquid, $V_f = 0.001002\ m^3/kg$
   Specific internal energy of saturated liquid, 134 kJ/kg

b. Superheated ammonia vapour at $30^\circ C$, 10bar
   Specific volume: $0.1321\ m^3/kg$
   Specific internal energy = 1347 kJ/kg

1.c. Steam enters a 15cm diameter horizontal pipe as saturated vapour at 5 bar with a velocity of 10m/s and exit at 4.5 bar and a quality of 0.95. Heat is transferred to surroundings at 300K from the pipe surface which is at an average temperature of 400K. Under the steady state operating conditions, determine:

(i) The exit velocity

(ii) The rate of heat transfer from pipe surface in kW

(iii) The rate of entropy production in kW/K, for the control volume comprising of only pipe and its contents and

(iv) The rate of entropy production for the enlarged control volume that includes pipe, its contents and the immediate surroundings.

[10]

Properties of steam at saturation condition:

P bar	t_{sat} $^\circ C$	Sp. Volume m^3/kg		Sp. Enthalpy kJ/kg		Sp. Entropy $kJ/kg \cdot K$	
		Liquid (v_f)	Vapour (v_g)	Liquid (h_f)	Vapour (h_g)	Liquid (s_f)	Vapour (s_g)
4.5	147.93	0.001088	0.4140	623.5	2744	1.8207	6.8565
5.0	151.86	0.001093	0.3749	640.0	2749	1.8607	6.8213

1.d. i. A certain gas obeys the equation of state, $P(v-a)=RT$. Show that the ratio of its volume expansivity, β with that of an ideal gas, β_{ideal} and the ratio of its isothermal compressibility, K_T with that of an ideal gas, $K_{T,ideal}$ are given by

$$\frac{\beta}{\beta_{ideal}}=\frac{RT}{RT+ap} \text{ and } \frac{K_T}{K_{T,ideal}}=1-\left(\frac{a}{v}\right)$$

ii. For a substance with volume expansivity, $\beta>0$, show that at every point of single phase region (vapour region) on a Mollier diagram, the slope of constant pressure line is greater than the slope of constant temperature line but less than that of constant volume line. [6+9]

2.a. Explain with a neat sketch, the working principle of a hybrid rocket engine. What are the advantages of this engine? [10]

b. What are the different types of combustion chambers in CI engine? Explain with a neat sketch, an open combustion chamber. What are the merits and demerits of the open combustion chamber? [10]

c. A four stroke single cylinder petrol engine mounted on a motor cycle was put to load test. The load measured on dynamometer was 30kg with drum diameter and speed respectively at 900mm and 2000rpm. The engine consumed 0.15kg of fuel in one minute, the calorific value of fuel being 43.5 MJ/kg. The fuel supply to the engine was stopped and was driven by a motor which needed 5kW of power to keep it running at the same speed, the efficiency of the motor being 80%. The engine cylinder bore and stroke are respectively at 150mm and 200mm. Calculate [10]

(i) Brake Power

(ii) Indicated Power

(iii) Mechanical efficiency

(iv) Brake thermal efficiency

(v) Indicated thermal efficiency

(vi) Brake mean effective pressure

(vii) Indicated mean effective pressure

d. The overall thermal efficiency of a 5MW nuclear power plant for a submarine is 30%. Calculate the amount of natural uranium, U^{235}, needed to generate the power if the average energy release per fission for U^{235} is 190MeV. Take $W=6.241\times10^{12}\,MeV/s$. Avogadro's Number is 6.02×10^{23}. [10]

3.a. Cooling water at a steady rate of 0.5kg/s flows through an inner tube having inner diameter of 25mm and length 10m of a tube-in-tube condenser. The mean inlet temperature of cooling water is 10ºC. Saturated steam condenses in the annulus at a uniform rate such that the inner surface temperature of the tube is constant throughout the length of the tube at 40ºC. The average condensing side heat transfer coefficient is $10000\ W/m^2K$. Neglect the thickness of the heat exchanger tube. Calculate the effectiveness of the heat exchanger and the exit water temperature. [15]

Properties of water are given below:

Specific heat: $4180\ \text{J/kg}\cdot\text{K}$

Density: $990\text{kg}/\text{m}^3$

Dynamic viscosity: $0.8\times10^{-3}\,\text{Pascal}\cdot\text{sec}$

Thermal conductivity: $0.57\text{W}/\text{m}\cdot\text{K}$

You may use the relation $\text{Nu} = \text{Re}_d^{\ 0.8}\,\text{Pr}^{0.4}$

3.b. The net radiation from the surfaces of two plates having equal emissivities of 0.8 and at different temperatures T_1 and T_2 [T_1>T_2] is to be reduced by 90%. How many numbers of radiation screens having equal emissivities of 0.05 are to be placed between the plates to achieve the reduction in heat exchange? [15]

3.c. What is an expansion device? Explain with the help of neat sketch, the working principle of a thermostatic expansion valve(TEV)

4.a. An R-12 vapour compression plant producing 10 tonnes of refrigeration operates with condensing and evaporating temperatures of 35ºC and -10ºC respectively. A suction line heat exchanger is used to sub-cool the saturated liquid leaving the condenser. Saturated vapour leaving the evaporator is superheated in the suction line heat exchanger to the extent that a discharge temperature of 60ºC is obtained after isentropic compression. Calculate

(i) The sub-cooling achieved in the heat exchanger

(ii) The refrigerant flow rate in kg/s

(iii) The cylinder dimensions of the two cylinder compressor, if the speed is 900 rpm, stroke-to-bore ratio is 1:1 and the volumetric efficiency is 80%.

(iv) The COP of the plant and

(v) The power required to drive the compressor in kW.

Draw the cycles on P-h and T-s diagrams. You may use the following table:

Temperature ^{o}C	Sp. Volume m^3/kg	Sp. Enthalpy kJ/kg		Sp. Entropy $\text{kJ}/\text{kg}\cdot\text{K}$	
	Vapour (v_g)	Liquid (h_f)	Vapour (h_g)	Liquid (s_f)	Vapour (s_g)
-10	0.0766	190.88	347.13	0.9660	1.5600
+35	0.0206	233.50	365.92	1.1139	1.5419

Average specific heat of desuper heating vapour at condenser = $0.796\ \text{kJ/kg}\cdot\text{K}$

Average specific heat of vapour between evaporator outlet and

Compression suction = $0.658\ \text{kJ/kg}\cdot\text{K}$ [20]

b. A rectangular fin of length 30cm, width 30cm and thickness 2mm is attached to a surface at 300ºC. The fin is made of aluminium $\left(K = 204 W / mK\right)$ and is exposed to air at 30ºC. The fin end is uninsulated and can loose heat through its end also. The convection heat transfer coefficient between the fin surface and air is $15 W / m^2 \cdot K$.

Determine: [10]

(i) The temperature of the fin at 30cm from the base

(ii) The rate of heat transfer from the fin and

(iii) Fin efficiency.

c. Briefly describe the various methods of air-conditioning duct design. [10]

5.a. A tank with the vertical sides measuring 3m x 3m contains water to a depth of 1.2m. An oil of density 900 kg/m^3 was poured in the tank upto a depth of 0.8m. The vertical wall can withstand the thrust of 58kN. Calculate the actual thrust on the wall and centre of pressure. If the oil level is increased up to 0.9m, what will be stability of the wall? [10]

5.b. For a rate of flow exceeding certain value, the coefficient of discharge for a venturimeter used for measuring the discharge of an incompressible fluid is found to be constant. Prove that the loss of head in the convergent portion of the venturi can be expressed as KQ^2 under these conditions, where K is a constant (function of cd, areas of the venturimeter) and Q is flow rate in m^3 / s. What will be the value of K, assuming the cd constant? [10]

5.c. A straight inclined pipeline 300m long discharges freely at a point 50m lower than the water surface at intake. The pipe intake projects into the reservoir $\left(k_e = 0.8\right)$. The first 200m of the pipe is of 350mm diameter and the remaining 100m is of 250mm diameter $\left(k_c = 0.21\right)$. [10]

i. Find the rate of discharge assuming f = 0.06.

If the junction point C of the two sizes of the pipe is 40m below the intake water surface level, find the pressure head.

ii. Just upstream of C and

iii. Just downstream of C

Assume sudden contraction at C.

iv. Verify the head loss across contraction C.

5.d. Two pipes have length L each. One of them has a diameter D and other d. If the pipes are arranged in parallel, the head loss is h for a discharge of Q m^3/s. When the pipes are connected in series, the head lost is H for same discharge. Find the ratio of H to h for D = 2.25d. (All dimensions are in mm) [10]

6.a. Develop (in general terms) an expression for the percent of error in Q over a triangular weir if there is a small error in the measurement of the vertex angle. Assume there is no error in the weir coefficient. Compute the percent error in Q, if there is a 1° error in the measurement of total vertex angle of a triangular weir which is having a total vertex angle of 60º. [10]

6.b. What is the hydraulic jump in the flow in open channel? What are its types and characteristics with respect to Froude's number of flow? [10]

6.c. Air flows isothermally in a long pipe. At one section the pressure is 600kPa abs., the temperature is 25ºC and the velocity is 30m/s. At a second section (at some distance from the first section) the pressure is 100kPa abs. Find the energy head loss due to friction and determine the thermal energy that must have been added to or taken from the fluid between the two sections. Assume the diameter of pipe to be constant. [10]

6.d. Researchers plan to test a 1:13 model of a ballistic missile in a high speed wind tunnel. The prototype missile will travel at 380m/s through air at 23ºC and 95.0kPa (abs). [10]

i. If the air in the wind tunnel test section has a temperature of -20ºC at a pressure of 89kPa (abs) what must its velocity be? And

ii. Estimate the drag force on the prototype if the drag force on the model is 400N.

7.a. Explain the effect of vane angle on manometric efficiency in a centrifugal pump. Why is vane angle in a centrifugal pump not kept at values below 20º? [10]

7.b. Fluid flows with a velocity of V_∞ over a flat plate located at y = 0. The leading edge of the plate is located at x = 0. The possible velocity profiles in the boundary layer having thickness $\delta(x)$ are as follows:

i. $$\frac{u}{V_\infty} = 2\frac{y}{\delta} - \left(\frac{y}{\delta}\right)^2$$

ii. $$\frac{u}{V_\infty} = \frac{3}{2}\frac{y}{\delta} - \frac{1}{2}\left(\frac{y}{\delta}\right)^2$$

iii. $$\frac{u}{V_\infty} = \frac{y}{\delta} - \frac{1}{2}\left(\frac{y}{\delta}\right)^2$$

Find out which of these velocity profiles are feasible for laminar flow. Also, identify the smoothest velocity profile from these three options. [10]

7.c. Describe with neat sketch, the construction and working principle of Rotometer. What are its advantages?

7.d. A single acting reciprocating pump lifts a liquid of specific weight $9.0\ \text{kN/m}^3$ from a pressurised storage reservoir to an overhead container. The free surface in the supply reservoir is at an elevation of 3.5m above the centre of the pump. The ambient pressure over the liquid surface in the supply reservoir is $27\ \text{kN/m}^2$ (vacuum). The other relevant data relating to the pump are as follows:

Length of the suction pipe = 6.0m

Diameter of suction pipe = 10cm

Atmospheric pressure = 99 kN/m^2 (abs)

Determine the maximum speed admissible in rpm. [10]

8.a. Define air rate, specific power and the cycle work ratio in a gas turbine. What is the significance of these parameters? [5]

8.b. Justify the selection of a turbine runner with highest speed possible. Derive an expression for the specific speed of a pelton wheel, for speed ratio 0.46, overall efficiency 85% and coefficient of velocity of nozzle 0.98. [10]

8.c. What are the shortcomings of a fire tube boiler restricting it for limited use? How are the impurities in feed water removed from the boiler? [10]

8.d. What are the constructional features of an axial flow compressor? How air is compressed and what is the method of getting higher compression ratio in such compressor? [5]

8.e. A gas turbine utilizes two-stage centrifugal compressor. The pressure ratios for the first and second stages are 2.5 and 2.1 respectively. The flow of air is 10kg/s, this air being drawn at 1.013 bar and 20ºC. If the temperature drop in the intercooler is 60ºC and the isentropic efficiency is 90% for each stage, calculate:

i. The actual temperature at the end of each stage and

ii. The total compressor power.

Assume $\gamma = 1.4$ and $C_p = 1.005$ kJ/kg·K for air. [10]