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IES

Engineering Services Examination - UPSC

MECHANICAL ENGINEERING

Topic-wise Conventional Papers I & II (Last 30 Years Questions)

Dedicated to Mechanical Engineers

and Engineering Services aspirants.

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A word to the students

Er. R.K. Rajesh
(DIRECTOR)

Engineering services examination offers one of the most promising and prestigious careers for service to the nation. Over the past few years, it has become more competitive as a number of aspirants are increasingly becoming interested in government jobs due to decline in other career options and reputation and future security.

In my opinion, ESE rigorously tests candidates' overall understanding of concepts, ability to apply their knowledge and personality level by screening them through various stages. A candidate is supposed to smartly deal with the syllabus not just mugging up concepts. Thorough understanding with critical analysis of topics and ability to express clearly are some of the pre-requisites to crack this exam. The syllabus and questioning pattern has remained pretty much the same over the years. Conventional paper practice is very important to score good marks, as it checks your writing skills, deep understanding of a subject.

Mechanical engineers prefer ESE over other options due to attractive career options and diverse departments. Railways, Central engineering services and other departments are highly sought after. General category cut-off in ESE 2012 was 532/1200 and a total 169 candidates were finally recommended in ESE 2012. For more details visit our website www.engineersinstitute.com

Established in 2006 by a team of IES and GATE toppers, we at **Engineers Institute of India-E..I.I.** have consistently provided rigorous classes and proper guidance to engineering students over the nation in successfully accomplishing their dreams. We believe in providing exam-oriented teaching methodology with updated study material and test series so that our students stay ahead in the competition. The faculty at EII are a team of experienced professionals who have guided thousands to aspirants over the years. They are readily available before and after classes to assist students and we maintain a healthy student-faculty ratio. Many current and previous year toppers associate with us for contributing towards our goal of providing quality education and share their success with the future aspirants. Our results speak for themselves. Past students of EII are currently working in various departments and PSU's and pursuing higher specializations. We also give scholarships to meritorious students.

A detailed solution of the past years conventional questions, prepared by toppers, will be available very soon.

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MECHANICAL ENGINEERING

ENGINEERING SERVICES EXAMINATION

CONVENTIONAL PAPER-I

(Last 30 Years Questions)

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1. THERMODYNAMICS

Last 30 Years Questions

Paper 1985

1. (***a***) A cylinder closed at both ends is thermally insulated from the surroundings. It contains a movable, thermally insulated, frictionless and leak proof piston. Initially the pressure, volume and temperature on each side of the piston are p_0, V_0 and T_0. The number of moles of gas on each side is *n*. Heat is now slowly supplied to the gas on the left side of the piston by an electric heating coil. As a result the gas on the left-hand side expands and displaces the piston, compressing the gas on the right-hand side until its pressure reaches $\left(\frac{27}{8}\right)p_0$. If the ratio of specific heats $\left(\frac{C_p}{C_v}\right)$ is 1.5 of *n*, C_v, M and T_0 (*i*) the work done on the gas on the right-hand side, (*ii*) the final temperature of the gas on the right-hand side, (*iii*) the final temperature of the gas on the left hand side and (*iv*) the heat supplied to the gas on the left-hand side. All assumptions made must be clearly stated.

(***b***) Two reversible heat engines E_1 and E_2 are kept in series between a hot reservoir at a temperature T_1 of 600 K and a cold reservoir at a temperature T_3 of 300 K. Engine E_1 receives 500 kJ of heat from the reservoir at T_1. The thermal efficiency of both the engines is the same. Determine (*i*) the temperature at which heat is rejected by engine E_1 and received by engine E_2, (*ii*) work done by engine E_1, (*iii*) work done by engine E_2, (*iv*) heat rejected by engine E_2 to the cold reservoir and (*v*) the efficiency of the engines.

Paper 1986

2. (***a***) During some integral number of complete cycles a reversible heat engine absorbs 2800 kJ from a heat reservoir at 1000 K and performs 800 kJ mechanical work. The engine exchanges heat with two other heat reservoirs one of which is 5400 K and the other at 600 K. Determine the heat exchanged (whether absorbed or rejected) with these two reservoirs, the change in entropy of each of the three reservoirs and the change in the entropy of the universe. Draw a NEAT sketch of the system.

(***b***) An engine in outer space operates on the Carnot cycle. The only way in which heat is rejected by the engine to the surroundings is by radiation which is property not to the product of the fourth power of the absolute temperature of the radiating surface and its area. For a given power output of the engine, hot reservoir temperature T_1 and radiator temperature T_2 determine the ratio $\left(\frac{T_1}{T_2}\right)$ for which the area of the radiating surface as a minimum.

(*c*) A system maintained at constant volume is initially at temperature T_1. If a heat reservoir at temperature T_0 – which is less than T_1 – is available, determine the maximum work obtainable as the system is cooled to T_0 in terms of T_0, T_1 and C_v.

Paper 1987

3. Two identical bodies of constant heat capacity are at the same initial temperature T_1. A refrigerator operates between these two bodies until one body is cooled to the temperature T_2. If the bodies remain at constant pressure and undergo no change of phase, obtain an expression for the minimum amount of work required to achieve this.

Paper 1988

4. A mass m of water at T_1 is isobarically and adiabatically mixed with an equal mass of water T_2. Show that

$$\Delta S_{\text{total}} = 2m\,C_p \ln \frac{\frac{(T_1 + T_2)}{2}}{\sqrt{T_1 T_2}}$$

Paper 1989

5. (*a*) A reversible heat engine operates between 600 C and 40 C and drives a reversible refrigerator operating between 40 C and –18 C. Still there is a net output of work equal to 370 kJ, while the heat received by the engine is 2100 kJ. Determine the cooling effect.

(*b*) A compressor takes in 500 kg/min of air at 0.98 bar and 18 C and delivers it at 5.5 bar and 68 C. The diameters of inlet and delivery pipes are respectively 450 mm and 200 mm. The power input is 1000 kW. Determine the rate and direction heat flow. (C_V = 1.005 kJ/kg C).

6. A reversible cycle using an ideal gas as the working substance consists of a isentropic compression from an initial temperature to 555ºK, a constant volume process from 555º to 835º K, a reversible adiabatic expansion to 555º K, a constant pressure expansion from 555º K to 835º K followed by a constant volume process to the initial temperature. Draw the cycle on p-v and the T.S. diagrams and determine the initial temperature. ($\gamma = 1.40$). Also compute the work done.

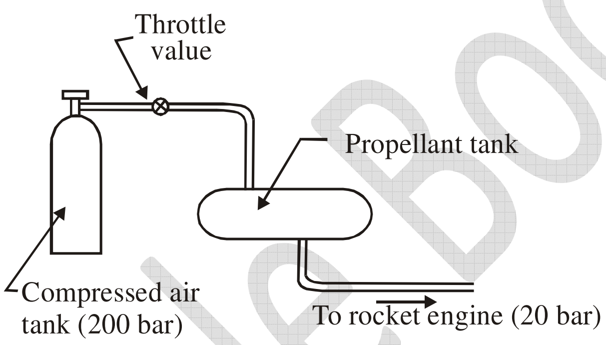
Paper 1990

7. (*a*) A rigid tank of $0.566\,m^3$ volume contains air at 6.895 bar and 21.1 C. The tank is equipped with a relief valve that opens at a pressure of 8.618 bar and remains open until the pressure drops to 8.274 bar. If a fire causes the valve to operate once as described, determine the air temperature just before the valve opens and the mass of air lost due to the fire. Assume that the temperature of the air remains constant during discharge and air in the tank behaves as an ideal gas.

(*b*) The scales are so chosen that a reversible cycle plots clockwise as a circle on the T-S plane. The minimum and maximum values of the temperature are 305 and 627 K and the entropy 1.23 and 2.85 kJ/K, respectively. Find the cycle work and efficiency.

Paper 1991

8. (*a*) Discuss flow energy. Compressed air is used to expel the liquid propellant from the propellant tank as shown below. The initial pressure of the air is 200 bar. The propellant has a density of 1.12 gm/cc and the propellant tank is filled to capacity and contains 900 kg of propellant. The propellant leaves at a constant pressure of 200 N/ cm^2 (20 bar). Considering the air as the system, determine the work done by the air in forcing the propellant from the propellant tank. Determine the volume of compressed air tank necessary to pump all the fuel in the rocket. Would the use of helium instead of air alter the performance? Is the inlet air temperature is of any consequence?



(*b*) The steam, initially at a pressure of 15 bar and temperature of 250 C, expand reversibly and poly-tropically to 1.5 bar. Find the final temperature, work done, and change of entropy, if the index of expansion is 1.25. (Assume 1 bar = $1\,kgf/cm^2$. State the assumptions made.)

9. (*a*) A reversible engine receives heat from a mixture of water vapour and liquid water at 1 atm and rejects 3775 kJ/hr of heat at 100º K below temperature of a mixture of ice and liquid water at 1 atm. It delivers 0.386 kW power. Find the number of degrees separating absolute zero and ice point on Kelvin scale.

(*b*) A working fluid goes through a Carnot cycle of operations, the upper absolute temperature of the fluid being θ_1 and the lower absolute temperature being θ_2. The amount of heat taken in and rejected by the working fluid are Q_1 and Q_2 respectively. On account of losses of heat due to conduction etc., the heat source temperature T_1 is higher than θ_1 and the heat sink temperature T_2 is lower than θ_2. If $T_1 = (\theta_1 + KQ_1)$; $T_2 = (\theta_2 - KQ_2)$ where K is the same constant for both the equations, show that the efficiency of the plant is given by

$$\eta = 1 - \frac{T_2}{T_1 - 2KQ_2}$$

10. (*a*) Starting from first law equation $dQ = du + pdv$ show that change in entropy of an ideal gas system is given *b*.

$$\Delta s = C_v \ln \frac{T_2}{T_1} + R \ln \frac{V_2}{V_1}$$

(*b*) A system operating in a reversible cycle receives 25 kJ of heat at 225 C (1 – 2). This is followed by an adiabatic expansion (2 – 3) to 115 C at which temperature 15 kJ of heat is received (3 – 4). Then a further adiabatic expansion (4 – 5) to 32 C occurs after which 25 kJ of heat is rejected at constant temperature (5 – 6) followed by an adiabatic compression (6 – 7). Find the change in entropy during the last process (7 – 1) which occurs after adiabatic compressions (6 – 7) to 115 C.

Paper 1992

11. (*a*) 3 kg of air at 1.50 bar pressure and 87º C temperature at condition 1 is compressed poly-tropically to condition 2 at pressure 7.50 bar, index of compression being 1.2. It is then cooled at constant pressure to condition 3 and then finally heated at constant temperature to its original condition 1. Find the net work done and heat transferred.

(*b*) 500 kJ of heat is removed from a constant temperature heat reservoir maintained at 835 K. The heat is received by a system at constant temperature of 720 K. The temperature of the surroundings, the lowest available temperature is 280 K. Illustrate the problem by T – S diagram and calculate the net loss of available energy as a result of this irreversible heat transfer.

Paper 1993

12. (*a*) 0.5 kg of air (ideal gas) executes a Carnot power cycle having a thermal efficiency of 50 percent. The heat transfer to the air during the isothermal expansion is 40 kJ. At the beginning of the isothermal expansion the pressure is 7 bar and the volume is 0.12 m^3. Determine the maximum and minimum temperatures for the cycle, in K, the volume at the end of isothermal expansion, in m^3, and the work and heat transfer for each of the four processes, in kJ. For air $C_v = 0.721$ and $C_p = 1.008$ kJ/kg.K.

(*b*) Steam flows through an adiabatic steady flow turbine. The enthalpy at entrance is 4142 kJ/kg and at exit 2585 kJ/kg. The values of flow availability of steam at entrance and exit are 1787 kJ/kg and 140 kJ/kg, respectively. If the dead state temperature T_o is 300 K, determine, per kg of steam, the actual work, the maximum possible work for the given change of state of steam, and the change in entropy of steam. Neglect changes in kinetic and potential energy.

13. (*a*) A compressed air bottle of $0.05\,m^3$ volume contains air at 3.5 atm pressure. This air is used to drive a turbo-generator supplying power to a device which consumes 5 W. Calculate the time for which the device can be operated if the actual output of the turbo-generator is 60 percent of the maximum theoretical output. The ambient pressure is 1 atm. For air, $\left(\frac{C_p}{C_V}\right) = 1.4$.

(*b*) An insulated vessel is divided into two compartments connected by a valve. Initially, one compartment contains steam at 10 bar, 500º C, and the other is evacuated. The valve is opened and the steam is allowed to fill the entire volume, achieving a final pressure of 1 bar. Determine the final temperature, in º C, the percentage of the vessel volume initially occupied by steam and the amount of entropy produced, in kJ/kg.K.

Paper 1994

14. (*a*) A Piston-cylinder device contains 3 kg of wet steam at 1.4 bars. The initial volume is $2.25\,m^3$. The steam is heated until its temperature reaches 400º C. The piston is free to move up or down unless it reaches the stops at the top. When the piston is up against the stops the cylinder volume is $4.65\,m^3$. Determine the amounts of work and heat transfer to or from steam.

(*b*) An evacuated bottle of $0.5\,m^3$ volume is slowly filled from atmospheric air at 1.0135 bars until the pressure inside the bottle also becomes 1.0135 bars. Due to heat transfer, the temperature of air inside the bottle after filling is equal to the atmospheric air temperature. Determine the amount of heat transfer.

15. Two blocks of metal, each of mess M and specific heat C, initially at absolute temperatures T_1 and T_2 respectively, are brought to the same final temperature by means of a reversible process. Derive an expression for the amount of work obtained during the process in terms of M, C, T_1 and T_2.

16. In an air-standard Brayton cycle the minimum and maximum temperatures are 300 K and 1200 K, respectively. The pressure ratio is that which maximizes the net work developed by the cycle per unit mass of air flow. Calculate the compressor and turbine work, each in kJ/kg air, and the thermal efficiency of the cycle.

Paper 1995

17. (*a*) A tank containing 40 kg of water, initially at 40º C, has one inlet and one exit with equal mass flow rates. Water enters the tank at 40º C at the rate of 200 kg/hr. Energy is removed from the water at the rate of 8 kW by means of a cooling coil immersed in the water. The water is well mixed by a mechanical stirrer that the water temperature in the tank is uniform. The power input to the water from the stirrer is 0.3 kW. Derive an expression for the variation of water temperature in the tank with time. The specific heat of water is 4.2 kJ/kg.K. Neglect kinetic and potential energy effects.

(*b*) A closed system executes a reversible cycle 1-2-3-4-5-6-1 consisting of six processes. During processes 1-2 and 3-4 the system receives 1000 kJ and 800 kJ of heat, respectively, at constant temperatures of 500 K and 400 K, respectively. Processes 2-3 and 4-5 are adiabatic expansions in which the system temperature is reduced from 500 K to 400 K and from 400 K to 300 K, respectively. During process 5-6 the system rejects heat at a constant temperature of 300 K. Process 6-1 is an adiabatic compression process. Determine the work done by the system during the cycle and the thermal efficiency of the cycle.

18. A rigid vessel is divided into two parts A and B by means of a frictionless, perfectly conducting piston. Initially, part A contains 0.4 m^3 of air (ideal gas) at 10 bars pressure and part B contains 0.4 m^3 of wet steam at 10 bars. Heat is now added to both parts until all the water in part B is evaporated. At this condition the pressure in part B is 15 bars. Determine the initial quality of steam in part B and the total amount of heat added to both parts.

Paper 1996

19. (***a***) 0.14 m^3 of steam at 20 bar and 250º C is expanded reversibly and poly-tropically to 2 bar. Find the final temperature, work done, heat transferred and change of entropy, if the index of expansion is 1.25.

(***b***) The specific heats of gas are of the form $C_p = a + kT$ and $C_V = b + kT$, where *a, b* and *k* are constants and T is in K. Derive the formula $T^b v^{a-b} e^{kt}$ = constant, for adiabatic expansion of the gas.

(***c***) A closed system contains 0.5 kg of air. It expands from 2 bar, 60º C to 1 bar, 40º C. During expansion it receives 2 kJ of heat from a reservoir at 100º C. Assuming atmospheric conditions to be at 0.95 bar and 30º C, calculate (*i*) the maximum, work, (*ii*) work done on atmosphere, and (*iii*) change in availability.

Paper 1997

20. (***a***) An ideal gas is heated from temperature T_1 to T_2 by keeping its volume constant. The gas is expanded back to its initial temperature according to the law pv^n = constant. If the entropy changes in the two processes are equal, find the value of *n* in terms of the adiabatic index γ.

(***b***) A cylinder contains one kg of water and steam at a pressure of 3.8 bar and 0.4 dry. Heat is supplied at constant volume until the pressure reaches to 10 bar. The steam is then expanded according to the law *pv* = constant, until the pressure is 2 bar. Calculate

(*i*) Heat transfer during constant volume heating.
(*ii*) Heat transfer during *pv* = constant expansion.
(*iii*) Temperature of steam after the expansion.

(***c***) An adiabatic cylinder of volume 10 m^3 is divided into two compartments A and B, each of volume 6 m^3 and 4 m^3 respectively, by a thin sliding partition. Initially the compartment A is filled with air at 6 bar and 600 K, whilst there is a vacuum in the compartment B. Suddenly the partition is removed, the fluid in compartment A expands and fills both the compartments. Calculate the loss in available energy. Assume atmosphere is at 1 bar and 300 K.

Paper 1998

21. (*a*) Using the Maxwell relation derive the following T*ds* equation

$$T\,ds = C_p\,dT - T\left(\frac{\delta v}{\delta t}\right)_p dp$$

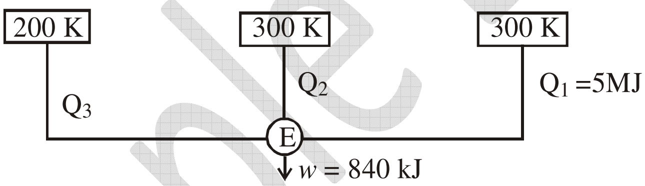
(*b*) A compressed air bottle of volume $0.15\ m^3$ contains air at 40 bar and 27º C. It is used to drive a turbine which exhausts to atmosphere at 1 bar. If the pressure in the bottle is allowed to fall to 2 bars, determine the amount of work that could be delivered by the turbine.

(*c*) A rigid tank contains air at 1.5 bar and 60º C. The pressure of air is raised at 2.5 bar by transfer of heat from a constant temperature reservoir at 400º C. The temperature of surroundings is 27º C. Determine per kg of air, the loss of available energy due to heat transfer.

Paper 1999

22. (*a*) Show that the cyclic integral of $\frac{dQ}{T}$ for a reversible cycle is equal to zero.

(*b*)



A reversible engine as shown in the above figure during a cycle of operation draws 5 MJ from the 400 K reservoir and does 840 kJ of work. Find the amount and direction of heat interaction with other reservoirs.

(*c*) Exhaust gases leave an internal combustion engine at 800º C and 1 atmosphere, after having done 1050 kJ of work per kg of gas in the engine (C_p of gas = 1.1 kJ/kg K). The temperature of the surroundings is 30º C.
(*i*) How much available energy per kg of gas is lost by throwing away the exhaust gases?
(*ii*) What is the ratio of the lost available exhaust gas energy to the engine work?

23. What are the differences between heat pump and refrigeration cycle?
What is the relation between (C.O.P.) Heat pump and (C.O.P.) Refrigerator? What are the differences between Kelvin Planck and Clausius Statements of 2^{nd} Law?

Paper 2000

24. (*a*) A reversible engine receives equal quantity of heat from two reservoirs A and B maintained at temperatures T_1 and T_2 respectively. The engine rejects heat to a reservoir C at temperature T_3. In case the thermal efficiency of the above engine is K times, the efficiency of reversible engine receiving heat only from reservoir A and rejecting heat to reservoir C and also if the heat supplied by the reservoir C and also if the heat supplied by the reservoir A is the same as it supplied in the combined case show that:

$$K = \frac{1}{2}\left\{\left[\frac{(T_2 - T_3)}{(T_1 - T_3)}\right] + \left(\frac{T_2}{T_1}\right)\right\} \times \left(\frac{T_1}{T_2}\right)$$

(*b*) A heat source at 627º C transfer heat at the rate of 3000 kJ/min. to a system maintained at 287º C. A heat sink is available at 27º C. Assuming these temperatures to remain constant, find:

(*i*) change in entropy of source
(*ii*) Entropy production accompanying heat transfer
(*iii*) The original available energy
(*iv*) The available energy after heat transfer

Paper 2001

25. (*a*) Using Maxwell's relations, show that for a pure substance

$$T\,ds = C_p\,dT - Tv\beta\,dp$$

$$= C_v\,dT + T\frac{\beta}{K}\,dv = \frac{KC_v\,dp}{\beta} + \frac{C_p}{\beta_v}\,dv$$

where β is coefficient of cubical expansion, K is coefficient of compressibility and C_p and C_v are specific heats at constant pressure and at constant volume respectively.

(*b*) State the Calusius inequality in words.

An inventor claims that he has developed a heat engine which absorbs 1200 kJ and 800 kJ from reservoirs at 800 K and 600 Kelvin respectively and rejects 600 kJ and 200 kJ as heat to reservoirs at 400 K and 300 K respectively. It delivers 1200 kJ work. Determine whether the heat engine is theoretically possible.

(*c*) A mass *m* of fluid at temperature T_1 is mixed with an equal mass of the same fluid at temperature T_2. Prove that the resultant change entropy of the universe is

$$2\,mc\,\frac{\frac{(T_1 + T_2)}{2}}{\sqrt{T_1\,T_2}}1$$

Paper 2002

26. (*a*) An insulated tank of $1\,m^3$ volume contains air at 0.1 MPa and 300 K. The tank is connected to a high pressure line in which air at 1 MPa and 600 K flows. The tank is quickly filled with air by opening the valve between the tank and high pressure line. If the final pressure of air in the tank is 1 MPa, determine the mass of air which enters the tank and the entropy change associated with filling process.
Take Universal Gas Constant $\bar{R}$ = 8.314 kJ/kg-mol-k. **(20)**

(*b*) By using Maxwell's relations of thermodynamics, show that Joule-Thomson coefficient, μ of gas can be expressed as, **(10)**

$$\mu = \left(\frac{\partial T}{\partial p}\right)_h = \frac{T^2}{C_p}\left[\frac{\partial}{\partial T}\left(\frac{v}{T}\right)\right]_p$$

(*c*) A heat driven refrigeration system absorbs heat from low temperature T_E and rejects it to temperature T_C. This is run by heat supplied from a high temperature source at temperature $T_H, T_H > T_C > T_E$. Using first and second laws of thermodynamics derive the expression for maximum COP of refrigeration system in terms of temperature. **(10)**

Paper 2003

27. (*a*) Explain the terms (*i*) coefficient of cubical expansion, β and (*ii*) coefficient of compressibility K. Hence, show that $\frac{\beta}{K} = \left(\frac{\partial P}{\partial T}\right)_v$. **(5)**

(*b*) Using Maxwell's and other equations, show that

$$C_p - C_v = \left\{P + \left(\frac{\partial u}{\partial v}\right)_T\right\}\left(\frac{\partial v}{\partial T}\right)_P$$

Hence show that $C_p - C_v = \beta^2 T \frac{v}{K}$. **(10)**

(*c*) A reversible engine 'A' absorbs energy from a reservoir at temperature T_1 and rejects energy to a reservoir at temperature T_2. A second engine 'B' absorbs the same amount of energy as rejected by engine 'A', from the same reservoir at temperature T_2 and rejects energy to a reservoir at temperature T_3. What will be the relation between T_1, T_2 and T_3 if (*i*) the efficiencies of both the engines 'A' and 'B' are the same and (*ii*) the work delivered by both the engines is the same? **(15)**

(*d*) An ideal gas is heated at constant volume until its temperature is 3 times the original temperature, then it is expanded isothermally till it reaches its original pressure. The gas is then cooled at constant pressure till it is restored to the original state. Determine the net work done per kg of gas if the initial temperature is 350 K. **(10)**

Paper 2004

28. (***a***) Derive the following Clapeyron Clausius-Clapeyron equations:

$$\frac{dp}{dT} = \frac{h_{fg}}{T(V_g - V_f)} \text{ and } \frac{dp}{p} = \frac{h_{fg}}{RT^2} dT.$$

Explain the physical significance of these equations. **(10)**

(***b***) A heat pump operates between two identical bodies. In the beginning, both the bodies are at the same temperature T_1 but operation of heat pump cools down one of the body to temperature T_3. Show that for the operation of heat pump the minimum work input needed by the heat pump for unit mass is given

$$W_{min} = c\left[\frac{T_1^2}{T_2} + T_2 - 2T_1\right]$$

where c is the specific heat of bodies.

Discuss whether the system satisfies first and second law of thermodynamics or not. **(10)**

(***c***) A large vessel contains steam at a pressure of 20 bar and a temperature of 350º C. This large vessel is connected to a steam turbine through a valve followed by a small initially evacuated tank with a volume of $0.8\,m^3$. During emergency power requirement, the valve is opened and the tank fills with steam until the pressure is 20 bar. The temperature of the tank is then 400º C. Assume that the filling process takes place adiabatically and the changes in potential and kinetic energies are negligible. By drawing the control volume, calculate the amount of work developed by the turbine in kJ. **(20)**

Paper 2005

29. (***a***) Derive the expression for $(\Delta h)_T$ for a substance that obeys the equation of state given by: $p = \frac{RT}{\upsilon} - \frac{a^2}{\upsilon^2}$ **(10)**

(***b***) 4 kg of water at 40º C are mixed with 6 kg of water at 100º C in a steady flow process. Calculate:

(*i*) the temperature of resulting mixture,

(*ii*) the change in entropy, and

(*iii*) the unavailable energy with respect to the energy receiving water at 40º C. **(10)**

(***c***) An inventor claims to have developed a device which requires no energy transfer by work or heat transfer, yet able to produce hot and cold stream of air from a single stream of air at an intermediate temperature of 21º C and a pressure of 5.2 bar, separate streams of air exit at a temperature of 1 bar. Sixty percent of mass entering the device exists at the lower temperature. Evaluate the inventor's claim, assuming ideal gas as working fluid and neglecting changes in kinetic and potential energy. **(20)**