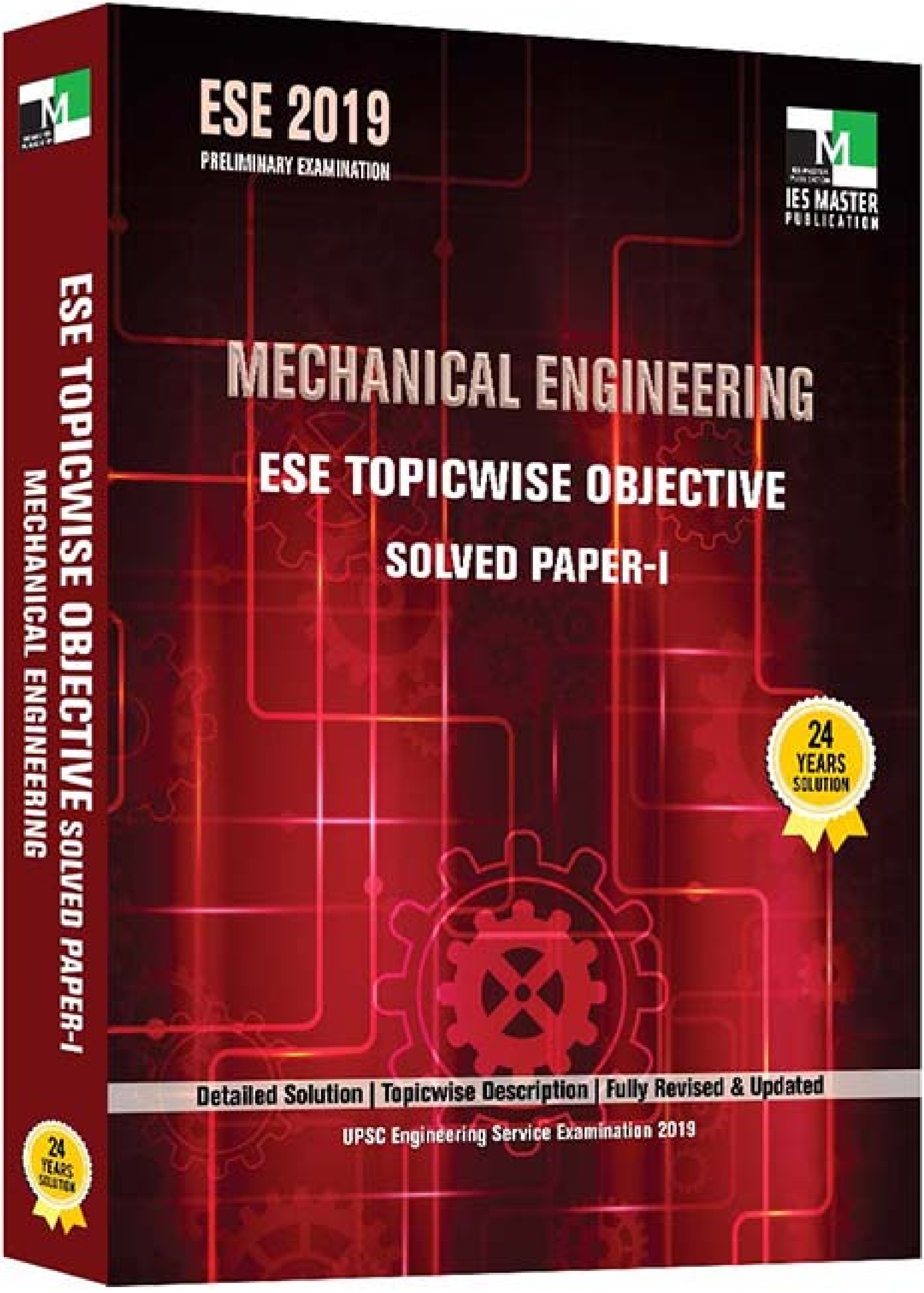
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PREFACE

It is an immense pleasure to present topic wise previous years solved paper of Engineering Services Exam. This booklet has come out after long observation and detailed interaction with the students preparing for Engineering Services Exam and includes detailed explanation to all questions. The approach has been to provide explanation in such a way that just by going through the solutions, students will be able to understand the basic concepts and will apply these concepts in solving other questions that might be asked in future exams.

Engineering Services Exam is a gateway to a immensly satisfying and high exposure job in engineering sector. The exposure to challenges and opportunities of leading the diverse field of engineering has been the main reason for students opting for this service as compared to others. To facilitate selection into these services, availability of arithmetic solution to previous year paper is the need of the day. Towards this end this book becomes indispensable.

Mr. Kanchan Kumar Thakur
Director–IES Master

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Unit 1 Thermodynamics

SYLLABUS

Thermodynamic systems and processes; properties of pure substances; Zeroth, First and Second Laws of Thermodynamics; Entropy, Irreversibility and availability; analysis of thermodynamic cycles related to energy conversion : Rankine, Otto, Diesel and Dual Cycles; ideal and real gases; compressibility factor; Gas mixtures.

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CHAPTER 1

Introduction and First Law

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1. Which one of the following substances has constant specific heat at all pressures and temperature ?

(a) Mono-atomic gas (b) Di-atomic gas

(c) Tri-atomic gas (d) Poly-atomic gas

2. When the valve of an evacuated bottle is opened, the atmospheric air rushes into it. If the atmospheric pressure is 101.325 kPa and 0.6 m^3 of air enters into the bottle, then the work done by the air will be

(a) 80.8 kJ (b) 70.8 kJ

(c) 60.8 kJ (d) 50.8 kJ

3. A thermodynamic cycle is composed of four processes. The heat added and the work done in each process are as follows :

Process	Heat transfer (J)	Work done (J)
1 – 2	0	50 (by the gas)
2 – 3	50 (from the gas)	0
3 – 4	0	20 (on the gas)
4 – 1	80 (to the gas)	0

The thermal efficiency of the cycle is

(a) 20.3% (b) 37.5%

(c) 40.3% (d) 62.5%

4. A steel tank placed in hot environment contains 5 kg of air at 4 atm at 30°C. A portion of the air is released till the pressure becomes 2 atm. Later, the temperature of the air in the tank is found to be 150°C. The quantity of air allowed to escape is

(a) 4.72 kg (b) 4.12 kg

(c) 3.71 kg (d) 3.21 kg

5. Consider the following statements :

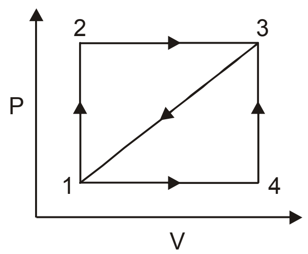
1. Entropy is related to the first law of thermodynamics.
2. The internal energy of an ideal gas is a function of temperature and pressure.
3. The zeroth law of thermodynamics is the basis for measurement of temperature.

Which of the above statements are correct ?

(a) 1 and 2 only (b) 1 and 3 only

(c) 2 and 3 only (d) 1, 2 and 3

6. A system absorbs 100 kJ as heat and does 60 kJ work along the path 1-2-3. The same system does 20 kJ work along the path 1-4-3. The heat absorbed during the path 1-4-3 is



(a) –140 kJ (b) –80 kJ

(c) 80 kJ (d) 60 kJ

IES – 2017

7. **Statement (I):** The specific heat at constant pressure for an ideal gas is always greater than the specific heat at constant volume.

Statement (II): Heat added at constant volume is not utilized for doing any external work.

8. During a constant pressure expansion of a gas, 33.3% heat is converted into work while the temperature rises by 20 K. The specific heat of the gas at constant pressure as a proportion of work, W is

(a) 8% (b) 10%
(c) 12% (d) 15%

IES – 2016

9. Consider the following processes :

1. Extension of a spring
2. Plastic deformation of a material
3. Magnetization of a material exhibiting hysteresis

Which of the above process are irreversible?

(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

10. Which of the following statements are correct for a throttling process?

1. It is an adiabatic steady flow process
2. The enthalpy before and after throttling is same
3. In the processes, due to fall in pressure, the fluid velocity at outlet is always more than inlet velocity

(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

11. **Statement (I) :** Thermometers using different thermometric property substance may give different readings except at two fixed points.

Statement (II) : Thermodynamic temperature scale is independent of any particular thermoemtric substance.

12. **Statement (I) :** First law of thermodynamics analyses the problem quantitatively whereas second law of thermodynamics analyses the problem qualitatively.

Statement (II) : Throttling process is reversible process.

13. Which one of the following statements is correct during adiabatic charging of an ideal gas into an empty cylinder from a supply main?

(a) The specific enthalpy of the gas in the supply main is equal to the specific enthalpy of the gas in the cylinder
(b) The specific enthalpy of the gas in the supply main is equal to the specific internal energy of the gas in the cylinder
(c) The specific internal energy of the gas in the supply main is equal to the specific enthalpy of the gas in the cylinder
(d) The specific internal energy of the gas in the supply main is equal to the specific internal energy of the gas in the cylinder

14. Consider the following systems :

1. An electric heater
2. A gas turbine
3. A reciprocating compressor

The steady flow energy equation can be applied to which of the above systems?

(a) 1 and 2 only (b) 1 and 3 only
(c) 1, 2 and 3 (d) 2 and 3 only

15. Consider the following conditions for the reversibility of a cycle :

1. The P and T of the working substance must not differ appreciably, from those of the surroundings at any state in the process.
2. All the processes, taking place in the cycle, must be extremely slow.
3. The working parts of the engine must be friction-free.

Which of the following conditions are correct?

(a) 1, 2 and 3 (b) 1 and 2 only
(c) 1 and 3 only (d) 2 and 3 only

16. The property of a thermodynamic system is :

(a) A path function
(b) A point function
(c) A quantity which does not change in reversible process
(d) A quantity which changes when system undergoes a cycle

ANSWER KEY

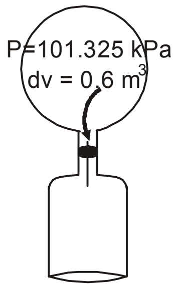
1.	(a)	33.	(d)	65.	(d)	97.	(c)
2.	(c)	34.	(b)	66.	(a)	98.	(c)
3.	(b)	35.	(a)	67.	(b)	99.	(b)
4.	(d)	36.	(d)	68.	(d)	100.	(b)
5.	(*)	37.	(c)	69.	(a)	101.	(a)
6.	(d)	38.	(a)	70.	(a)	102.	(d)
7.	(a)	39.	(b)	71.	(b)	103.	(c)
8.	(d)	40.	(c)	72.	(d)	104.	(d)
9.	(c)	41.	(b)	73.	(b)	105.	(a)
10.	(a)	42.	(d)	74.	(b)	106.	(b)
11.	(b)	43.	(c)	75.	(c)	107.	(b)
12.	(c)	44.	(b)	76.	(b)	108.	(b)
13.	(b)	45.	(a)	77.	(a)	109.	(a)
14.	(c)	46.	(c)	78.	(b)	110.	(b)
15.	(a)	47.	(d)	79.	(d)	111.	(b)
16.	(b)	48.	(a)	80.	(b)	112.	(d)
17.	(c)	49.	(d)	81.	(b)	113.	(c)
18.	(b)	50.	(b)	82.	(b)	114.	(a)
19.	(b)	51.	(c)	83.	(b)	115.	(b)
20.	(b)	52.	(a)	84.	(d)	116.	(b)
21.	(b)	53.	(a)	85.	(a)	117.	(c)
22.	(d)	54.	(d)	86.	(d)	118.	(b)
23.	(c)	55.	(a)	87.	(c)	119.	(b)
24.	(c)	56.	(a)	88.	(b)	120.	(c)
25.	(d)	57.	(d)	89.	(a)	121.	(d)
26.	(a)	58.	(c)	90.	(b)	122.	(c)
27.	(c)	59.	(b)	91.	(b)	123.	(d)
28.	(d)	60.	(d)	92.	(b)	124.	(a)
29.	(a)	61.	(d)	93.	(c)	125.	(a)
30.	(a)	62.	(c)	94.	(a)		
31.	(b)	63.	(d)	95.	(d)		
32.	(a)	64.	(c)	96.	(d)		

SOLUTION...

Sol–1 (a)

Sol–2 (c)

Work done by air



$= Pdv$

$= 101.325 \times 0.6$

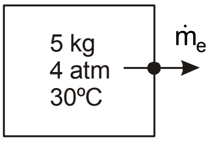
$= 60.8$ kJ

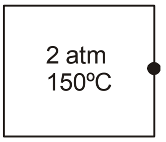
Sol–3 (b)

Thermal efficiency,

$$\eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{50}{80} = 37.5\%$$

Sol–4 (d)





From mass conservation,

$$\dot{m}_i - \dot{m}_e = \frac{d}{dt}m_{cv} = m_2 - m_1$$

(1) No inlet, so $\dot{m}_i = 0$

$\therefore \dot{m}_e = m_1 - m_2$ ...(i)

(2) $m_1 = 5$kg (given)

$(P_1V = mRT_1)$

$$m_2 = \frac{P_2V}{RT_2} = \frac{P_2}{RT_2}\left(\frac{m_1RT_1}{P_1}\right)$$

$$= \frac{2}{423} \times \frac{5 \times 303}{4} = 1.79 \text{ kg}$$

From equation (i) $\dot{m}_e = 5 - 1.79 = 3.21$ kg

Sol–5 (*)

Sol–6 (d)

For process 1 – 2 –3

$$Q_{123} = U_3 - U_1 + W_{123}$$

$U_3 - U_1 = Q_{123} - W_{123} = 100 - 60 = 40$ kJ

For process 1 – 4 – 3

$$Q_{143} = U_3 - U_1 + W_{143}$$
$$= 40 + 20 = 60 \text{ kJ}$$

Sol–7: (a)

The specific heat of ideal gas of constant pressure is the sum of specific heat at constant volume and a constant term. This constant term comes due to work done component. This work done component is missing when heat is added at constant volume.

Sol–8: (d)

The work done during expansion,

$$W = 0.333\ Q$$

Because heat added,

$$Q = C_p\Delta T$$

Because work done,

$$W = 0.333 C_p\Delta T$$

$$\therefore \frac{C_p}{W} = \frac{1}{0.333 \times \Delta T} = \frac{1}{0.333 \times 20}$$

$$\frac{C_p}{W} = \frac{100}{0.333 \times 20} = 15\%$$

Sol–9: (c)

A proces is reversible if both the system and surroundings are restored to initial condition. Thus, plastic deformation of a material and magnetization of a material exhibiting hysteresis are irreversible processes. The spring after extension will get back to its original position after removal of load, hence it can be considered as reversible.

Sol–10: (a)

Throttling process involves the passage of a higher pressure fluid through a narrow constriction. This process is adiabatic, and there is no work interaction. Hence,

$Q = 0$ & $W = 0$

$$\Delta PE = 0$$

(Inlet and outlet are at the same level)

$\Delta KE = 0$

(KE does not change significantly)

$\therefore$ Applying the SFEE, $h_1 = h_2$

Thus, enthalpy remain constant

Further, the velocity of flow is kept low and any difference between the kinetic energy upstream and downstream is negligible. The effect of the decrease in pressure is an increase in volume.

Sol–11: (b)

Thermodynamic or absolute temperature scale is independent of any working substance. The fact that the efficiency of a reversible heat engine cycle depends only on the temperature of the two reservoirs makes it possible to establish such a scale. If the temperature of a given system is mesured with thermometers using different thermoemetric properties, there is considerable difference among the readings.

Sol–12: (c)

Throttling process is a irreversible process as the entropy of the fluid increases during the process. The first law of thermodynamics only gives a quantitative estimate of the heat and work interaction between the system and surroundings, however, it does not state about quality of energy. It is the second law of thermodynamics which deals with the low grade and high grade energy and concepts of availability.

Sol–13: (b)

For charging the tank,

$$m_p h_p = m_2 u_2 - m_1 u_1$$

If the tank is initially empty, then $m_1 = 0$

$$\therefore \quad m_p h_p = m_2 u_2$$

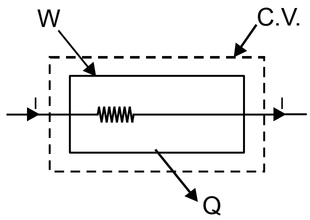
Since $m_p = m_2$, hence, $h_p = u_2$

Sol–14: (c)

The reciprocating compressor can be considered as steady flow system provided the control volume includes the receiver which reduces the fluctuation of flow.

For electric heater, at steady state

$$W = Q$$



Sol–15: (a)

A reversible process must be quasi-static and frictionless.

Further, a heat engine cycle in which there is a temperature difference (i) between the source and the working fluid during heat supply, and (ii) between the working fluid and the sink during heat rejection, exhibits external thermal irreversibility. Thus, P and T of the working substance must not differ, appreciably from those of the surroundings at any state in the process.

Sol–16: (b)

The propety of a thermodynamic system is a point function, since for a given state, there is a definite value for each property. The change in a thermodynamic property of a system in a change of state is independent of the path the system follows during the change of state and depends only on the initial and final states of the system.

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