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ESE 2021

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Preliminary Examination

Mechanical Engineering

Topicwise **Objective** Solved Questions

Volume-I

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Director's Message

Engineering is one of the most chosen graduating field. Taking engineering is usually a matter of interest but this eventually develops into "purpose of being an engineer" when you choose engineering services as a carrier option.

B. Singh (Ex. IES)

Train goes in tunnel we don't panic but sit still and trust the engineer, even we don't doubt on signalling system, we don't think twice crossing over a bridge reducing our travel time; every engineer has a purpose in his department which when coupled with his unique talent provides service to mankind.

I believe *"the educator must realize in the potential power of his pupil and he must employ all his art, in seeking to bring his pupil to experience this power"*. To support dreams of every engineer and to make efficient use of capabilities of aspirant, MADE EASY team has put sincere efforts in compiling all the previous years' ESE-Pre questions with accurate and detailed explanation. The objective of this book is to facilitate every aspirant in ESE preparation and so, questions are segregated chapterwise and topicwise to enable the student to do topicwise preparation and strengthen the concept as and when they are read.

I would like to acknowledge efforts of entire MADE EASY team who worked hard to solve previous years' papers with accuracy and I hope this book will stand up to the expectations of aspirants and my desire to serve student fraternity by providing best study material and quality guidance will get accomplished.

B. Singh (Ex. IES)
CMD, MADE EASY Group

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UNIT

I

Fluid Mechanics

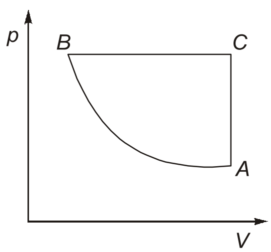
Syllabus

Fluid Mechanics: Basic concepts and Properties of fluids, Manometry, Fluid statics, Buoyancy, Equations of motion, Bernoulli's equation and applications, Viscous flow of incompressible fluids, Laminar and Turbulent flows, Flow through pipes and head losses in pipes.

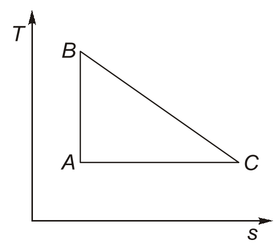
Contents

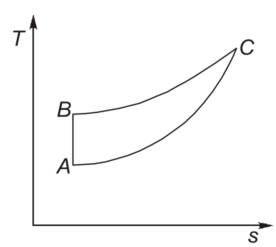
3 Second Law, Carnot Cycle and Entropy

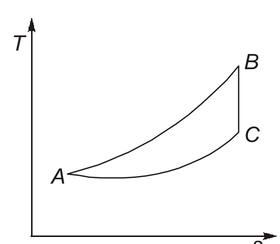
3.1 A cycle of pressure-volume diagram is shown in the given figure

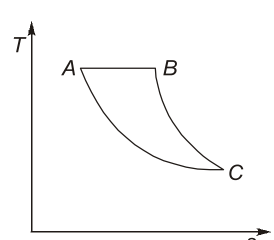


Same cycle on temperature-entropy diagram will be represented by

(a)


(b)


(c)


(d)


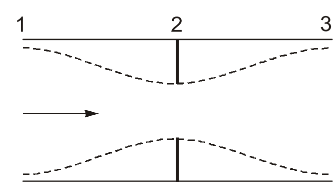
[ESE : 1995]

3.2 Which one of the following statements applicable to a perfect gas will also be true for an irreversible process? (Symbols have the usual meanings)

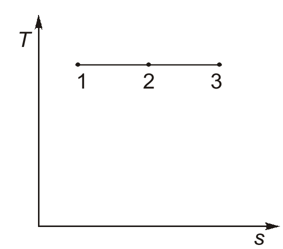
(a) $dQ = dU + pdV$ (b) $dQ = TdS$
(c) $Tds = dU + pdV$ (d) None of these

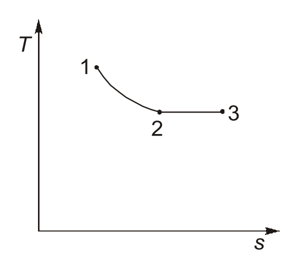
[ESE : 1996]

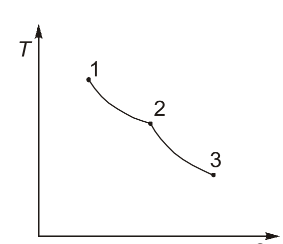
3.3 The throttling process undergone by a gas across an orifice is shown by its states in the following figure:

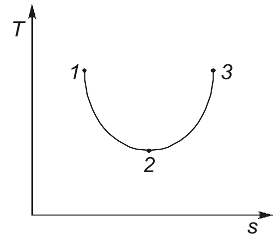


It can be represented on the diagram as

(a)


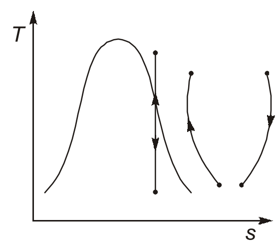
(b)


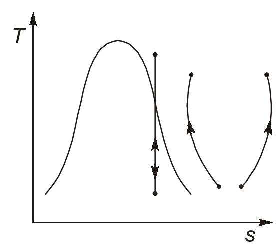
(c)


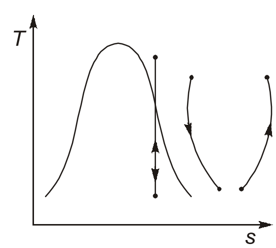
(d) 

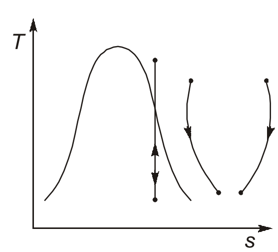
[ESE : 1996]

3.4 Which one on the following temperature entropy diagrams of steam shows the reversible and irreversible processes correctly?

(a) 

(b) 

(c) 

(d) 

[ESE : 1996]

3.5 When a system undergoes a process such that $\int \frac{dQ}{T} = 0$ and $\Delta S > 0$, the process is

(a) irreversible adiabatic
(b) reversible adiabatic
(c) isothermal
(d) isobaric

[ESE : 1997]

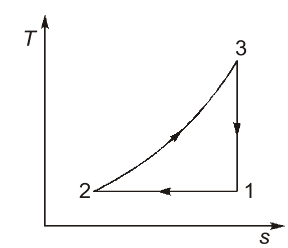
3.6 Consider the following statements:
When a perfect gas enclosed in a cylinder piston device executes a reversible adiabatic expansion process
1. Its entropy will increase.
2. its entropy change will be zero.
3. the entropy change of the surroundings will be zero.

Which of these statements is/are correct?
(a) 1 and 3 (b) 2 only
(c) 2 and 3 (d) 1 only [ESE : 1997]

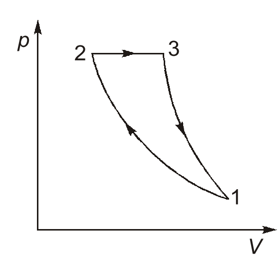
3.7 A system of 100 kg mass undergoes a process in which its specific entropy increases from 0.3 kJ/kgK to 0.4 kJ/kgK. At the same time, the entropy of the surroundings decreases from 80 kJ/K to 75 kJ/K.
The process is:
(a) Reversible and isothermal
(b) Irreversible
(c) Reversible
(d) Impossible

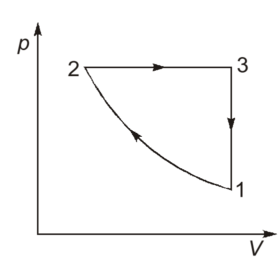
[ESE : 1997]

3.8 An ideal air standard cycle is shown in the given temperature-entropy diagram



The same cycle, when represented on the pressure-volume coordinates takes the form

(a) 

(b) 

3.15 Consider the following statements:
1. The first law of thermodynamics is a law of conservation of energy.
2. Perpetual motion machine of the first kind converts energy into equivalent work.
3. A closed system does not exchange work or energy with its surroundings.
4. The second law of thermodynamics stipulates the law of conservation of energy and entropy.

Which of these statements are correct
(a) 1 and 3 (b) 2 and 4
(c) 2, 3 and 4 (d) 1, 2 and 3

[ESE : 2000]

3.16 A heat engine receives 1000 kW of heat at a constant temperature of 285°C and rejects 492 kW of heat at 5°C. Consider the following thermodynamic cycles in this regard:
1. Carnot cycle
2. Reversible cycle
3. Irreversible cycle

Which of these cycles could possibly be executed by the engine?
(a) 1 only (b) 3 only
(c) 1 and 2 (d) None of 1, 2 & 3

[ESE : 2000]

3.17 Consider the following statements:
When dry saturated steam is throttled from a higher pressure to a lower pressure, the
1. pressure decreases and the volume increases.
2. temperature decreases and the steam becomes superheated.
3. temperature and the dryness fraction increase.
4. entropy increases without any change in enthalpy.

Which of these statements are correct?
(a) 1 and 4 (b) 1, 2 and 4
(c) 1 and 3 (d) 2 and 4

[ESE : 2000]

3.18 Consider the following statements:
A real gas obeys perfect gas law at very
1. high temperatures
2. high pressures
3. low pressures

Which of these statements is/are correct?
(a) 1 only (b) 1 and 3
(c) 2 only (d) 3 only

[ESE : 2000]

3.19 In which one of the following situations the entropy change will be negative:
(a) Air expands isothermally from 6 bars to 3 bars
(b) Air is compressed to half the volume at constant pressure
(c) Heat is supplied to air at constant volume till the pressure becomes three folds
(d) Air expands isentropically from 6 bars to 3 bars

[ESE : 2000]

3.20 The heat added to a closed system during a reversible process is given by $Q = \alpha T + \beta T^2$, where α and β are constants. The entropy change of the system as its temperature changes from T_1 to T_2 is equal to
(a) $\alpha + \beta(T_2 - T_1)$
(b) $[\alpha(T_2 - T_1) + \beta/2(T_2^2 - T_1^2]/T_1$
(c) $\dfrac{\left[\frac{\alpha}{2}\left(T_2^2 - T_1^2\right) + \frac{\beta}{3}\left(T_2^3 - T_1^3\right)\right]}{T_1^3}$
(d) $\alpha \ln\left(\dfrac{T_2}{T_1}\right) + 2\beta(T_2 - T_1)$

[ESE : 2000]

3.21 **Assertion (A):** In thermodynamic analysis, the concept of reversibility is that, a reversible process is the most efficient process.
Reasons (R): The energy transfer as heat and work during the forward process, as always identically equal to the energy transfer is heat and work, during the reversal of the process.

[ESE : 2001]

3.22 A reversible heat engine receives 6 kJ of heat from thermal reservoir at temperature 800 K, and 8 kJ of heat from another thermal reservoir at temperature 600 K. If it rejects heat to a third thermal reservoir at temperature 100 K, then the thermal efficiency of the engine is approximately equal to:
(a) 65% (b) 75%
(c) 80% (d) 85%

[ESE : 2002]

3.115 Consider the following statements:
1. The entropy of a pure crystalline substance at absolute zero temperature is zero.
2. The efficiency of a reversible heat engine is independent of the nature of the working substance and depends only on the temperature of the reservoirs between which it operates.
3. Carnot's theorem states that of all heat engines operating between a given constant temperature source and a given constant temperature sink, none has a higher efficiency than a reversible engine

Which of the above statement are correct?
(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3
[ESE : 2018]

3.116 Which of the following devices complies with the Clausius statement of the second law of thermodynamics?
(a) Closed-cycle gas turbine
(b) Internal combustion engine
(c) Steam power plant
(d) Domestic refrigerator [ESE : 2018]

3.117 A reversible Carnot engine operates between 27°C and 1527°C, and produces 400 kW of net power. The change of entropy of the working fluid during the heat addition process is
(a) 0.222 kW/K (b) 0.266 kW/K
(c) 0.288 kW/K (d) 0.299 kW/K
[ESE : 2018]

3.118 An ideal gas is flowing through an insulated pipe at the rate of 3 kg/s. There is a 10% pressure drop from an inlet to exit of the pipe. The values of $R = 0.287$ kJ/kg.K and $T_o = 300$ K. The rate of energy loss for the pressure drop due to friction, will be nearly
(a) 34 kW (b) 30 kW
(c) 26 kW (d) 22 kW
[ESE : 2020]

3.119 A cyclic heat engine operates between a source temperature of 800°C and a sink temperature of 30°C. The least rate of heat rejection per kW net output of engine will be nearly
(a) 0.2 kW (b) 0.4 kW
(c) 0.6 kW (d) 0.8 kW
[ESE : 2020]

■■■■

Answers Second Law, Carnot Cycle and Entropy

3.1 (b)	3.2 (c)	3.3 (d)	3.4 (c)	3.5 (a)	3.6 (c)	3.7 (b)	3.8 (a)	3.9 (d)
3.10 (b)	3.11 (c)	3.12 (c)	3.13 (c)	3.14 (d)	3.15 (*)	3.16 (d)	3.17 (b)	3.18 (b)
3.19 (b)	3.20 (d)	3.21 (b)	3.22 (d)	3.23 (c)	3.24 (c)	3.25 (b)	3.26 (a)	3.27 (a)
3.28 (a)	3.29 (c)	3.30 (c)	3.31 (d)	3.32 (c)	3.33 (b)	3.34 (b)	3.35 (b)	3.36 (d)
3.37 (c)	3.38 (d)	3.39 (b)	3.40 (a)	3.41 (c)	3.42 (b)	3.43 (b)	3.44 (a)	3.45 (b)
3.46 (a)	3.47 (c)	3.48 (d)	3.49 (c)	3.50 (b)	3.51 (d)	3.52 (b)	3.53 (c)	3.54 (c)
3.55 (c)	3.56 (c)	3.57 (b)	3.58 (c)	3.59 (d)	3.60 (d)	3.61 (a)	3.62 (c)	3.63 (d)
3.64 (b)	3.65 (d)	3.66 (d)	3.67 (b)	3.68 (c)	3.69 (d)	3.70 (c)	3.71 (c)	3.72 (c)
3.73 (c)	3.74 (c)	3.75 (c)	3.76 (c)	3.77 (d)	3.78 (c)	3.79 (d)	3.80 (d)	3.81 (b)
3.82 (b)	3.83 (c)	3.84 (c)	3.85 (a)	3.86 (b)	3.87 (c)	3.88 (c)	3.89 (b)	3.90 (b)
3.91 (*)	3.92 (c)	3.93 (c)	3.94 (b)	3.95 (d)	3.96 (a)	3.97 (d)	3.98 (b)	3.99 (b)
3.100 (c)	3.101 (b)	3.102 (c)	3.103 (b)	3.104 (d)	3.105 (b)	3.106 (c)	3.107 (c)	3.108 (b)
3.109 (c)	3.110 (b)	3.111 (b)	3.112 (c)	3.113 (c)	3.114 (*)	3.115 (d)	3.116 (d)	3.117 (b)
3.118 (c)	3.119 (b)							

Explanations Second Law, Carnot Cycle and Entropy

3.1 (b)

In p-V diagram

BC — constant pressure process

CA — constant volume process

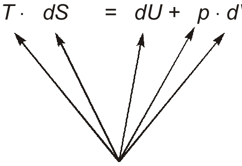
$$\because \left(\frac{dT}{ds}\right)_p = \frac{T}{c_p} \quad \text{and} \quad \left(\frac{dT}{ds}\right)_v = \frac{T}{c_v}$$

$$\therefore \quad c_p > c_v \quad \because \left(\frac{dT}{ds}\right)_v > \left(\frac{dT}{ds}\right)_p$$

Thus, slope of constant pressure (BC) is lower compare to slope of constant volume process (CA).

3.2 (c)

$$T \cdot dS = dU + p \cdot dV$$



All are properties thus it is applicable for reversible as well as irreversible process.

3.3 (d)

By applying steady flow energy equation for throttling process, $W = 0$, $Q = 0$

$$h_1 + \frac{C_1^2}{2} = h_2 + \frac{C_2^2}{2} = h_3 + \frac{C_3^2}{2}$$

(Assume $z_1 = z_2 = z_3$)

For gas

$$c_pT_1 + \frac{C_1^2}{2} = c_pT_2 + \frac{C_2^2}{2} = c_pT_3 + \frac{C_3^2}{2}$$

as $C\uparrow$, $T\downarrow$

From continuity equation:

$Q = AC$

For process 1-2:

as $A\downarrow$, $C\uparrow$, $T\downarrow$

For process 2-3:

as $A\uparrow$, $C\downarrow$, $T\uparrow$

3.4 (c)

In irreversible process entropy always increase only in option C entropy increases in both cases.

3.5 (a)

$$(\Delta S)_{\text{system}} = S_2 - S_1 = \int_1^2 \frac{\delta Q}{T} + S_{\text{gen}}$$

(S_{gen} is entropy generation i.e. some entropy is generated during irreversible process)

$$\Delta S = \int \frac{\delta Q}{T} = 0$$ implies adiabatic and reversible process. But if $\Delta S > 0$, it implies irreversible process.

3.6 (c)

The entropy change of the system will be zero as per Clausius inequality (principle of entropy). But the entropy change of the surrounding will be positive value.

$$(\Delta S)_{\text{total}} = (\Delta S)_{\text{system}} + (\Delta S)_{\text{surrounding}} \geq 0$$

3.7 (b)

$m = 100$ kg

Entropy of system,

$S_1 = 0.3 \times 100 = 30$ kJ/K

$S_2 = 0.4 \times 100 = 40$ kJ/K

Entropy change of the system,

$(\Delta s)_{\text{system}} = S_2 - S_1 = 40 - 30 = 10$ kJ/K

Entropy of surroundings,

$S_1 = 80$ kJ/K

$S_2 = 75$ kJ/K

Entropy change of the surroundings

$(\Delta S)_{\text{surrounding}} = S_2 - S_1$

$(\Delta S)_{\text{surroundings}} = -5$ kJ/K

Entropy change of universe:

$(\Delta S)_{\text{universe}} = (\Delta S)_{\text{system}} + (\Delta S)_{\text{surrounding}}$

$= 10 - 5 = 5$ kJ/K

Since $(\Delta S)_{\text{universe}} > 0$

Hence process is irreversible

3.8 (a)

In T–S diagram

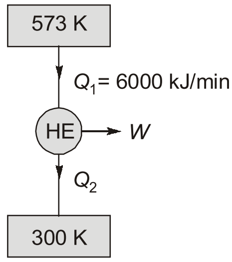
Process 1–2 $\rightarrow$ Isothermal process

Process 3–1 $\rightarrow$ Reversible adiabatic process

Thus, on P–V diagram, slope of reversible adiabatic

3.37 (c)

Heat source-1



$$\eta = \frac{W}{Q_1} = \frac{T_1 - T_2}{T_1}$$

$$\eta = \frac{T_1 - T_2}{T_1}$$

$$= 1 - \frac{300}{573}$$

$$= 0.476$$

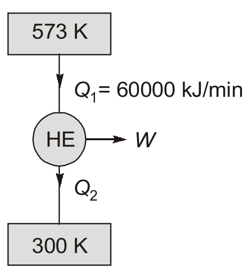
$$\eta = \frac{W}{Q_1}$$

$$0.476 = \frac{W_1}{6000}$$

$$\Rightarrow \quad W_1 = 2856 \text{ kJ/min}$$

Heat source-2

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



$$= 1 - \frac{300}{373}$$

$$= 0.1957$$

$$\eta = \frac{W}{Q_1}$$

$$0.1957 = \frac{W}{60000}$$

or $\quad W =$ **11742.62 kJ/min.**

3.38 (d)

For irreversible process

$$ds > \left(\frac{\delta Q}{T}\right)_{irr.}$$

$$\Rightarrow \quad ds = \left(\frac{\delta Q}{T}\right)_{irr} + (\delta s)_{generation}$$

Consider heat rejection from system

Let us take any arbitrary value.

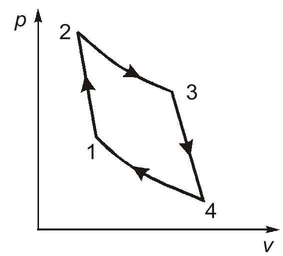
$$ds = -4 + 4 = 0$$

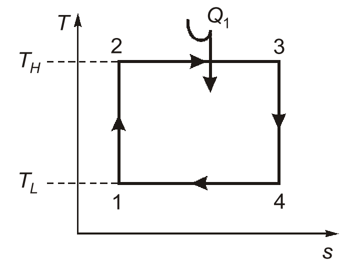
Thus isentropic process.

Thus an isentropic process may not be reversible adiabatic.

3.39 (b)

Given: $\quad \gamma = 1.4, \quad Q_1 = 52$ kJ





Expansion ratio,

$$\frac{V_4}{V_3} = 32$$

For expansion power 3 – 4,

$$T_H V_3^{\gamma-1} = T_L V_4^{\gamma-1}$$

or $$\frac{T_L}{T_H} = \left(\frac{V_3}{V_4}\right)^{\gamma-1} = \left(\frac{1}{32}\right)^{1.4-1} = 0.25$$

$$\eta_{Carnot} = 1 - \frac{T_L}{T_H} = 1 - 0.25 = 0.75$$

also $$\eta_{Carnot} = 1 - \frac{Q_2}{Q_1}$$

$$\therefore \quad 0.75 = 1 - \frac{Q_2}{52}$$

or $$\frac{Q_2}{52} = 0.25$$

or $\quad Q_2 =$ **13 kJ**

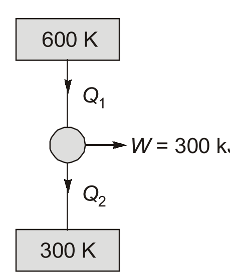
3.40 (a)

For any spontaneous process, the entropy of the universe increases. It is called principle of increase of entropy.

3.41 (c)

$$dS = \frac{\delta Q}{T} = \frac{ML^2T^{-2}}{\theta} = ML^2T^{-2}\theta^{-1}$$

3.43 (b)



$$\eta = \frac{T_1 - T_2}{T_1} = \frac{W}{Q_1}$$

$$\frac{W}{Q_1} = 1 - \frac{300}{600} = 0.5$$

$$Q_1 = \frac{300}{0.5} = 600 \text{ kJ}$$

$\therefore$ Change in entropy during heat addition

$$= \frac{Q_1}{T_1} = \frac{600}{600} = 1 \text{ kJ/K}$$