

19YEARS
PREVIOUS SOLVED PAPERS

GATE 2020

MECHANICAL ENGINEERING

(Fully Solved with Explanations)

*By
Team of
Engineers Academy*



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CONTENTS

S.No.	TOPIC	PAGE No.
1. THERMODYNAMICS		1 – 46
1.	ZEROTH LAW & BASIC CONCEPTS	3 – 7
2.	WORK & HEAT	8 – 14
3.	FIRST LAW OF THERMODYNAMICS	15 – 23
4.	SECOND LAW OF THERMODYNAMICS	24 – 29
5.	ENTROPY	30 – 39
6.	PROPERTY OF PURE SUBSTANCES	40 – 44
7.	AVAILABILITY	45 – 46
2. GAS CYCLE & GAS TURBINE		47 – 66
1.	AIR CYCLES	49 – 58
2.	GAS TURBINES	59 – 66
3. STEAM CYCLE & STEAM TURBINE		67 – 80
1.	RANKINE CYCLE	69 – 80
4. REFRIGERATION & AIR CONDITIONING		81 – 102
1.	REFRIGERATION	83 – 93
2.	PHYSCHROMETRY	94 – 102
5. INTERNAL COMBUSTION ENGINES		103 – 112
1.	INTERNAL COMBUSTION ENGINES	105 – 112
6. HEAT AND MASS TRANSFER		113 – 172
1.	CONDUCTION	115 – 135
2.	FINS & THC	136 – 141
3.	CONVECTION	142 – 151
4.	RADIATION	152 – 162
5.	HEAT EXCHANGERS	163 – 172

7. FLUID MECHANICS	173 – 256
1. PROPERTY OF FLUIDS	175 – 178
2. FLUID STATICS	179 – 187
3. FLUID KINEMATICS	188 – 207
4. FLUID DYNAMICS	208 – 222
5. LAMINAR FLOW	223 – 232
6. TURBULENT FLOW	233 – 236
7. BOUNDARY LAYER	237 – 243
8. TURBO MACHINERY	244 – 256
8. STRENGTH OF MATERIALS	257 – 330
1. SIMPLE STRESSES	259 – 272
2. COMPLEX STRESSES	273 – 281
3. SFD AND BMD	282 – 289
4. CENTROIDS AND MOMENT OF INERTIA	290 – 292
5. PURE BENDING	293 – 297
6. SHEAR STRESS IN BEAMS & SPRINGS	298 – 303
7. TORSION	304 – 310
8. SLOPES AND DEFLECTIONS	311 – 318
9. THIN CYLINDERS	319 – 324
10. COLUMNS AND STRUTS	325 – 327
11. STRAIN ENERGY	328 – 330
9. DESIGN OF MACHINE ELEMENTS	331 – 370
1. STATIC LOADING	333 – 336
2. FATIGUE	337 – 343
3. BOLTED, RIVETED AND WELDED JOINTS	344 – 352
4. GEARS	353 – 358
5. ROLLING CONTACT BEARINGS	359 – 360
6. SLIDING CONTACT BEARINGS	361 – 362
7. BRAKES AND SPRINGS	363 – 368
8. CLUTCHES	369 – 370

10. THEORY OF MACHINES	371 – 444
1. ANALYSIS OF PLANAR MECHANISM	373 – 386
2. DYNAMIC ANALYSIS OF SINGLE-CRANK MECHANISM	387 – 396
3. GEAR & GEAR TRAINS	397 – 407
4. FLY WHEELS, CAM AND FOLLOWER	408 – 414
5. MECHANICAL VIBRATIONS	415 – 442
6. BALANCING AND GYROSCOPE	443 – 444
11. ENGINEERING MECHANICS	445 – 498
1. FBD, PLANE TRUSSES	447 – 457
2. TRANSLATION AND ROTATION	458 – 466
3. FRICTION	467 – 474
4. WORK ENERGY AND IMPULSE (DYNAMIC ANALYSIS)	475 – 487
5. RIGID BODY MOTION	488 – 498
12. MATERIAL SCIENCE	499 – 510
1. MATERIAL SCIENCE	501 – 510
13. PRODUCTION ENGINEERING	511 – 684
1. CASTING	513 – 534
2. WELDING	535 – 554
3. METAL CUTTING	555 – 587
4. MACHINING	588 – 607
5. METAL FORMING	608 – 628
6. SHEET METAL OPERATIONS	629 – 640
7. METROLOGY	641 – 657
8. ADVANCED MACHINING METHODS	658 – 668
9. NONTRADITIONAL MACHINING METHODS	669 – 684

14. INDUSTRIAL ENGINEERING	685 – 750
1. LINEAR PROGRAMMING	687 – 698
2. PERT & CPM	699 – 709
3. QUEUING THEORY.....	710 – 715
4. INVENTORY CONTROL	716 – 725
5. TRANSPORTATION	726 – 728
6. PRODUCTION PLANNING & CONTROL	729 – 732
7. FORECASTING	733 – 738
8. LINE BALANCING	739 – 740
9. SCHEDULING	741 – 743
10. SEQUENCING	744 – 745
11. ASSIGNMENT	746 – 747
12. MATERIAL REQUIREMENT PLANNING	748 – 750

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MECHANICAL ENGINEERING

THERMODYNAMICS

GATE PREVIOUS YEARS Topicwise Solved Questions

Fully Solved with Explanations

Syllabus

Thermodynamic systems and processes; properties of pure substances, behaviour of ideal and real gases; zeroth and first laws of thermodynamics, calculation of work and heat in various processes; second law of thermodynamics; thermodynamic property charts and tables, availability and irreversibility; thermodynamic relations.

Try not to
become a man of success,
but rather try to
become a man of value.





ZEROTH LAW & BASIC CONCEPTS

OBJECTIVE QUESTIONS

1. Match items from groups, I, II, III, IV and V

Group-I	Group-II	Group-III	Group-IV	Group-V
	When added to the system is	Differential	Function	Phenomenon
E. Heat	G. Positive	I. Exact	K. Path	M. Transient
F. Work	H. Negative	J. Inexact	L. Point	N. Boundary

(a) F-G-J-K-M (b) E-G-I-K-M (c) F-H-J-L-N (d) E-G-J-K-N
 E-G-I-K-N F-H-J-K-N F-H-J-L-M F-H-J-K-M

[2 Marks : GATE-2006]

NOTES

2. The amount of heat lost by the air in the football and the gauge pressure of air in the football at the stadium respectively equal

(a) 30.6 J, 1.94 bar (b) 21.8 J, 0.93 bar
 (c) 61.1 J, 1.94 bar (d) 43.7 J, 0.93 bar

[2 Marks : GATE-2006]

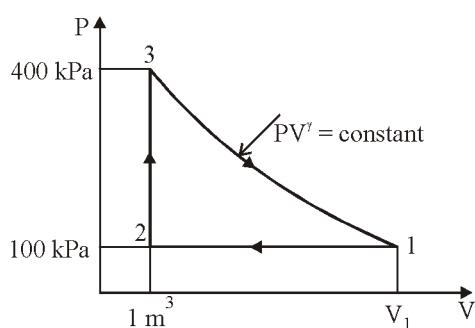
3. Gauge pressure of air to which the ball must have been originally inflated so that it would equal 1 bar gauge at the stadium is

(a) 2.23 bar (b) 1.94 bar (c) 1.07 bar (d) 1.00 bar

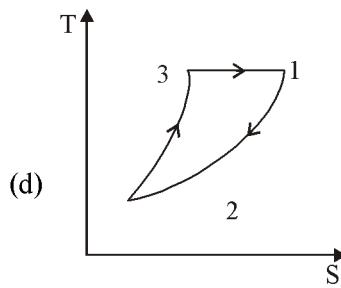
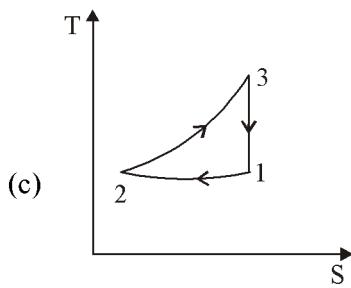
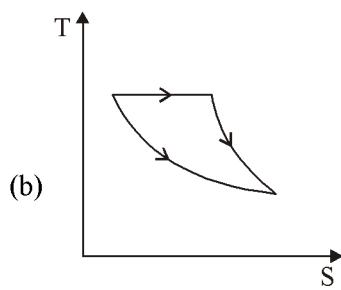
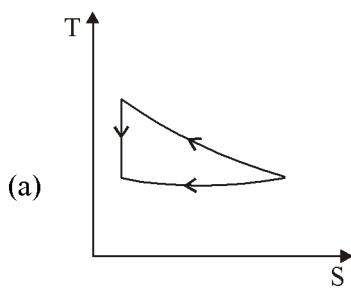
[2 Marks : GATE-2006]

Common Data for Question 4 and 5

A thermodynamics cycle with an ideal gas as working fluid is shown below



- 4 The above cycle is represented on T-s plane by



NOTES

[2007: 2 Marks]

- 5 If the specific heats of the working fluid are constant and the value of specific heat ratio γ is 1.4, the thermal efficiency (%) of the cycle is
 (a) 21 (b) 40.9 (c) 42.6 (d) 59.7

[2007: 2 Marks]

6. A piston-cylinder device initially contains 0.4 m^3 of air (to be treated as an ideal gas) at 100 kPa and 80°C . The air is now isothermally compressed to 0.1 m^3 . The work done during this process is _____ kJ.

[2 Marks : GATE-2016-Paper-1]

7. If one mole of H_2 gas occupies a rigid container with a capacity of 1000 liters and the temperature is raised from 27°C to 37°C , the change in pressure of the contained gas (round off to two decimal places), assuming ideal gas behavior, is _____ Pa. ($R = 8.314 \text{ J/mol.K}$).

[2 Marks : GATE-2019-Paper-I]

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ANSWERS AND EXPLANATIONS

1. Ans. (d)

Heat is positive when added to the system is an inexact differential, path function and boundary phenomenon.

Work is negative when added to the system, an inexact differential, path function and transient phenomenon.

2. Ans. (d)

Given,

Gauge pressure,

$$\begin{aligned} P_{G1} &= 1 \text{ bar} \\ &= 100 \text{ kPa} \end{aligned}$$

Ambient temperature,

$$\begin{aligned} T_1 &= 15^\circ\text{C} = (15+273) \\ &= 288 \text{ K} \end{aligned}$$

Absolute pressure,

$$\begin{aligned} P_1 &= P_{G1} + P_{atm} \\ &= 100 + 101.325 \\ &= 201.325 \text{ kPa} \end{aligned}$$

Volume,

$$\begin{aligned} V &= 2500 \text{ cm}^3 \\ &= 2500 \times 10^{-6} \text{ m}^3 \end{aligned}$$

Temperature,

$$\begin{aligned} T_2 &= 5^\circ\text{C} = (5 + 273) \\ &= 278 \text{ K} \end{aligned}$$

From equation of state,

$$P_1 V_1 = m R T_1$$

$$201.325 \times 2500 \times 10^{-6} = m \times 0.287 \times 288$$

$$m = 6.089 \times 10^{-3} \text{ kg}$$

Heat loss,

$$\begin{aligned} Q &= mc_v(T_1 - T_2) \\ &= 6.089 \times 10^{-3} (0.718) \\ &\quad (288 - 278) \times 1000 \\ &= 43.7 \text{ J} \end{aligned}$$

At

$$V = C$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\frac{201.325}{288} = \frac{P_2}{278}$$

$$P_2 = P_{G2} + P_{atm}$$

$$194.33 = P_{G2} + 101.325$$

$$P_{G2} = 93 \text{ kPa}$$

$$= 0.93 \text{ bar}$$

We can also do,

$$P_2 V = m R T_2$$

$$P_2 \times 2500 \times 10^{-6} = 6.089 \times 10^{-3} \times 0.287 \times 278$$

$$P_2 = 194.32 \text{ kPa}$$

$$\text{Also } P_2 = P_{G2} + P_{atm}$$

$$194.32 = P_{G2} + 101.325$$

$$P_{G2} = 93 \text{ kPa}$$

$$= 0.93 \text{ bar}$$

3. Ans. (c)

P_1 = Pressure to which it must be inflated

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\frac{P_1}{288} = \frac{201.325}{278}$$

$$\begin{aligned} P_1 &= 201.325 \times \frac{288}{278} \\ &= 208.56 \text{ kPa} \end{aligned}$$

Gauge pressure to which it must be inflated on previous day

$$= 208.56 - 101.3$$

$$= 107.24 \text{ kPa}$$

$$= 1.07 \text{ bar}$$

4. Ans. (c)

We can observe in the P-v diagram that temperature is not constant during any stage hence options (b) and (d) are rejected as temperature is constant during the stage 3-1 in both the options which is not possible option (a) is rejected because clockwise process in P-v diagram cannot have anticlockwise T-s diagram. Hence the correct option is (c)

5 Ans. (a)

The given cycle is Lenoir cycle for which thermal efficiency is given by

$$\eta = 1 - \frac{\gamma(r_p^{1/\gamma} - 1)}{r_p - 1}$$

Where

$$\gamma = 1.4$$

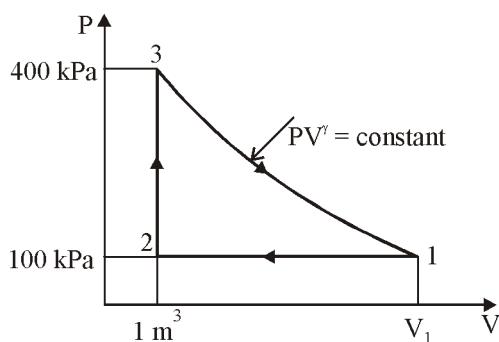
$$r_p = \frac{p_3}{p_2} = \frac{400}{100} = 4$$

∴

$$\eta = 1 - \frac{1.4 \left(\frac{\frac{1}{4^{1.4}} - 1}{4 - 1} \right)}{4 - 1}$$

$$= 21.05\%$$

Alternatively



process 2-3

$$Q_{2-3} = (U_3 - U_2) + W_{2-3}$$

$$Q_{2-3} = (U_3 - U_2) + 0$$

$$= mc_v(T_3 - T_2)$$

$$= mc_v \left(\frac{p_3 V_3}{mR} - \frac{p_2 V_2}{mR} \right)$$

$$= \frac{c_v}{R} (p_3 V_3 - p_2 V_2)$$

$$= \frac{c_v}{c_p - c_v} (400 \times 1 - 100 \times 1)$$

$$Q_{2-3} = \frac{1}{\gamma - 1} (400 - 100)$$

$$= \frac{300}{1.4 - 1} = \frac{300}{0.4} = 750 \text{ kJ}$$

$$Q_{1-2} = (U_2 - U_1) + W_{1-2}$$

$$= mc_v(T_2 - T_1) + p(V_2 - V_1)$$

$$= mc_v \left[\frac{p_2 V_2}{mR} - \frac{p_1 V_1}{mR} \right] + p(V_2 - V_1)$$

$$= \frac{c_v}{R} [p(V_2 - V_1)] + p(V_2 - V_1)$$

$$= p(V_2 - V_1) \left[\frac{c_v}{R} + 1 \right]$$

$$\therefore V_2 = 1 \text{ m}^3$$

$$= p(1 - V_1) \left\{ \frac{c_v}{c_p - c_v} + 1 \right\}$$

$$= 100 (1 - V_1) \left\{ \frac{1}{\gamma - 1} + 1 \right\}$$

Calculating V_1

$$P_3 V_3^\gamma = P_1 V_1^\gamma$$

$$\therefore V_1 = \left[\frac{P_3 \times V_3^\gamma}{P_1} \right]^{\frac{1}{\gamma}}$$

$$= \left[\frac{400}{100} \times 1 \right]^{\frac{1}{1.4}} = 2.692 \text{ m}^3$$

$$Q_{1-2} = 100 [1 - 2.692] \times \left\{ \frac{1}{0.4} + 1 \right\}$$

$$= -592.2 \text{ kJ}$$

(minus sign represent heat is rejected) there is no heat transfer in process 3-1 as it is reversible adiabatic process.

Efficiency of cycle.

$$\eta = 1 - \frac{Q_{\text{reject}}}{Q_{\text{added}}} = 1 - \frac{-592.2}{750}$$

$$= 0.2104 = 21.04\%$$

6. Ans. (-55 to -56) kJ

$$W = P_1 V_1 \ln \frac{V_2}{V_1}$$

$$= 100 \times 0.4 \ln \left(\frac{0.1}{0.4} \right)$$

$$= -55.45 \text{ kJ}$$

7. Ans. (83.14) MPa

No. of mole of H₂ = 1

Volume = 1000 lit

For rigid container = V₁ = V₂

$$T_1 = 27^\circ\text{C} + 273 = 300 \text{ K}$$

$$T_2 = 37 + 273 = 310 \text{ K}$$

For ideal gas

$$PV = nRT$$

$$P_1 V_1 = n R T_1$$

$$P_2 V_2 = n R T_2$$

$$(P_2 - P_1)V = nR[T_2 - T_1]$$

$$\Delta P \times V = nR[T_2 - T_1]$$

$$\Delta P = \frac{1 \times 8.314 \times 10}{1}$$

$$\Delta P = 83.14 \text{ MPa}$$

○○○



WORK AND HEAT

OBJECTIVE QUESTIONS

1. Nitrogen at an initial state of 10 bar, 1 m³ and 300 K is expanded isothermally to a final volume of 2 m³.

NOTES

The P-V-T relation is $\left(P + \frac{a}{V^2}\right)V = RT$, where $a > 0$. The final pressure

- (a) will be slightly less than 5 bar
- (b) will be slightly more than 5 bar
- (c) will be exactly 5 bar
- (d) cannot be ascertained in the absence of the value of (a)

[2 Marks : GATE-2005]

2. A 100 W electric bulb was switched on in a 2.5 m × 3 m × 3 m size thermally insulated room having a temperature of 20°C. The room temperature at the end of 24 hours will be

- (a) 321°C (b) 341°C (c) 450°C (d) 470°C

[2 Marks : GATE-2006]

3. In a steady state steady flow process taking place in a device with a single inlet and a single outlet, the work done per unit mass flow rate is given by

$w = - \int_{\text{inlet}}^{\text{outlet}} vdp$, where 'v' is the specific volume and 'p' is the pressure. The expression for 'w' given above

- (a) is valid only if the process is both reversible and adiabatic
- (b) is valid only if the process is both reversible and isothermal
- (c) is valid for any reversible

(d) is incorrect, it must be $w = \int_{\text{inlet}}^{\text{outlet}} pdv$

[2 Marks : GATE-2008]

4. A compressor undergoes a reversible, steady flow process. The gas at inlet and outlet of the compressor is designated as state 1 and state 2 respectively. Potential and kinetic energy changes are to be ignored. The following notations are used:

v = specific volume and P = pressure of the gas. The specific work required to be supplied to the compressor for this gas compression process is

- (a) $\int_1^2 Pdv$
- (b) $\int_1^2 v dP$
- (c) $v_1 (P_2 - P_1)$
- (d) $-P_2 (v_1 - v_2)$

[1 Mark : GATE-2009]

NOTES

5. A frictionless piston-cylinder device contains a gas initially at 0.8 MPa and 0.015 m³. It expands quasi-statically at constant temperature to a final volume of 0.030 m³. The work output (in kJ) during this process will be

(a) 8.32 (b) 12.00 (c) 554.67 (d) 8320.00

[2 Marks : GATE-2009]

6. Heat and work are

(a) intensive properties	(b) extensive properties
(c) point functions	(d) path functions

[1 Mark : GATE-2011]

7. The contents of a well-insulated tank are heated by a resistor of 23 Ω in which 10 A current is flowing. Consider the tank along with its contents as a thermodynamic system. The work done by the system and the heat transfer to the system are positive. The rates of heat (Q), work (W) and change in internal energy (ΔU) during the process in kW are

(a) Q = 0, W = - 2.3, ΔU = + 2.3
 (b) Q = + 2.3, W = 0, ΔU = + 2.3
 (c) Q = - 2.3, W = 0, ΔU = - 2.3
 (d) Q = 0, W = +2.3, ΔU = - 2.3

[1 Mark : GATE-2011]

8. A pump handling a liquid raises its pressure from 1 bar to 30 bar. Take the density of the liquid as 990 kg/m³. The isentropic specific work done by the pump in kJ/kg is

(a) 0.10 (b) 0.30 (c) 2.50 (d) 2.93

[1 Mark : GATE-2011]

9. A cylinder contains 5 m³ of an ideal gas at a pressure of 1 bar. This gas is compressed in a reversible isothermal process till its pressure increases to 5 bar. The work in kJ required for this process is

(a) 804.7 (b) 953.2 (c) 981.7 (d) 1012.2

[1 Mark : GATE-2013]

10. A certain amount of an ideal gas is initially at a pressure p₁ and temperature T₁. First, it undergoes a constant pressure process 1-2 such that T₂ = $\frac{3T_1}{4}$.

Then, it undergoes a constant volume process 2-3 such that T₃ = $\frac{T_1}{2}$. The ratio of the final volume to the initial volume of the ideal gas is

(a) 0.25 (b) 0.75 (c) 1.0 (d) 1.5

[2 Marks : GATE-2014-Paper-3]

11. The Vander Waals equation of state is $\left(p + \frac{a}{v^2}\right)(v - b) = RT$, where 'p' is pressure, 'v' is specific volume, 'T' is temperature and 'R' is characteristic gas constant. The SI unit of 'a' is

(a) J/kgK (b) m³/kg (c) m⁵/kg·s² (d) Pa/kg

[1 Mark : GATE-2015-Paper-2]

12. For an ideal gas with constant values of specific heats, for calculation of the specific enthalpy

- (a) it is sufficient to know only the temperature
- (b) both temperature and pressure are required to be known
- (c) both temperature and volume are required to be known
- (d) both temperature and mass are required to be known

NOTES**[1 Mark : GATE-2015-Paper-3]**

13. Temperature of nitrogen in a vessel of volume 2 m^3 is 288 K. A U-tube manometer connected to the vessel shows a reading of 70 cm of mercury (level higher in the end open to atmosphere). The universal gas constant is 8314 J/kmol-K atmospheric pressure is 1.01325 bar, acceleration due to gravity is 9.81 m/s^2 and density of mercury is 13600 kg/m^3 . The mass of nitrogen (in kg) in the vessel is

[2 Marks : GATE-2015-Paper-3]

14. A well insulated rigid container of volume 1 m^3 contains 1.0 kg of an ideal gas ($C_p = 1000 \text{ J/kgK}$ and $C_v = 800 \text{ J/kgK}$) at a pressure of 10^5 Pa . A stirrer is rotated at constant rpm in the container for 1000 rotations and the applied torque is 100 N-m. The final temperature of the gas (in K) is

[2 Marks : GATE-2015-Paper-3]

15. Which of the following statements are TRUE with respect to heat and work?
- (i) They are boundary phenomena
 - (ii) They are exact differentials
 - (iii) They are path functions
- | | |
|-------------------------|------------------------|
| (a) both (i) and (ii) | (b) both (i) and (iii) |
| (c) both (ii) and (iii) | (d) only (iii) |

[1 Mark : GATE-2016-Paper-1]

16. The internal energy of an ideal gas is a function of

- | | |
|------------------------------|-------------------------|
| (a) temperature and pressure | (b) volume and pressure |
| (c) entropy and pressure | (d) temperature only |

[1 Mark : GATE-2016-Paper-2]

17. An ideal gas undergoes a reversible process in which the pressure varies linearly with volume. The conditions at the start (subscript 1) and at the end (subscript 2) of the process with usual notation are: $p_1 = 100 \text{ kPa}$, $V_1 = 0.2 \text{ m}^3$ and $p_2 = 200 \text{ kPa}$, $V_2 = 0.1 \text{ m}^3$ and the gas constant, $R = 0.275 \text{ kJ/kgK}$. The magnitude of the work required for the process (in kJ) is

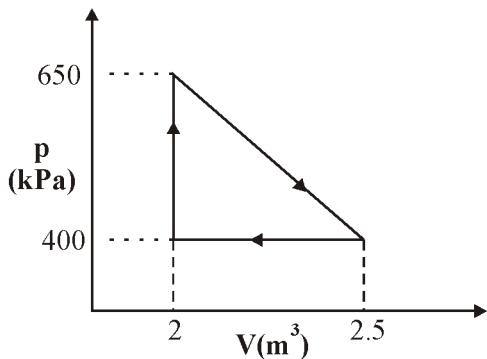
[2 Marks : GATE-2016-Paper-1]

18. A mass 'm' of a perfect gas at pressure P_1 and volume V_1 undergoes an isothermal process. The final pressure is P_2 and volume is V_2 . The work done on the system is considered positive. If R is the gas constant and T is the temperature, then the work done in the process is

- (a) $P_1 V_1 \ln \frac{V_2}{V_1}$
- (b) $-P_1 V_1 \ln \frac{P_1}{P_2}$
- (c) $RT \ln \frac{V_2}{V_1}$
- (d) $-mRT \ln \frac{P_2}{P_1}$

[1 Mark : GATE-2017-Paper-2]

19. An engine operates on the reversible cycle as shown in the figure. The work output from the engine (in kJ/cycle) is _____ (correct to two decimal places).

NOTES**[1 Mark : GATE-2018-Paper-2]**

20. A gas is heated in a duct as it flows over a resistance heater. Consider a 101 kW electric heating system. The gas enters the heating section of the duct at 100 kPa and 27°C with a volume flow rate of 15 m³/s. If heat is lost from the gas in the duct to the surroundings at a rate of 51 kW, the exit temperature of the gas is (Assume constant pressure, ideal gas, negligible change in kinetic and potential energies and constant specific heat : $C_p = 1 \text{ kJ/kg.K}$; $R = 0.5 \text{ kJ/kg.K}$).

- (a) 37°C (b) 76°C (c) 53°C (d) 32°C

[2 Marks : GATE-2019-Paper-I]

○○○

ANSWERS AND EXPLANATIONS

1. Ans. (b)

$$\left(P_1 + \frac{a}{V_1^2} \right) V_1 = \left(P_2 + \frac{a}{V_2^2} \right) V_2$$

$$\left(P_1 + \frac{a}{1} \right) 1 = \left(P_2 + \frac{a}{4} \right) 2$$

$$P_2 = 5 + \frac{a}{2}$$

As 'a' is positive P_2 is > 5

2. Ans. (d)

$$m C_v dT = \text{Power}$$

$$\rho V C_v dT = \frac{\text{Power}}{1000}$$

$$(2.5 \times 3 \times 3) (1.2) (0.718) (T - 20)$$

$$= 100 \times 3600 \times \frac{24}{1000}$$

$$19.386 (T - 20) = 8640$$

$$T = 465.6^\circ\text{C}$$

3. Ans. (c)

The energy balance for a steady flow device undergoing an internal reversible process can be expressed in differential form as

$$\partial q_{\text{rev}} - \partial W_{\text{rev}} = dh + d(\text{KE}) + d(\text{PE})$$

$$\text{But } \partial q_{\text{rev}} = TdS$$

$$\text{and } TdS = dh - vdP$$

$$\partial q_{\text{rev}} = dh - vdP$$

So,

$$dh - vdP - \partial W_{\text{rev}} = dh + d(\text{KE}) + d(\text{PE})$$

$$- \partial W_{\text{rev}} = vdP + d(\text{KE}) + d(\text{PE})$$

When K.E. and P.E. are negligible

$$W_{\text{rev}} = - \int_1^2 vdP$$

This is relation for reversible work output associated with an internal reversible process in a steady-flow device with change in kinetic energy and potential energy is zero.

4. Ans. (b)

The energy balance for a steady-flow device undergoing an internal reversible process can be expressed in differential form as

$$\partial q_{\text{rev}} - \partial W_{\text{rev}} = dh + d(\text{KE}) + d(\text{PE}) \dots (1)$$

As potential and kinetic energy are neglected
 $d(\text{KE}) = d(\text{PE}) = 0$

Also,

$$TdS = dh - vdP$$

For reversible process,

$$dS = 0$$

So,

$$dh = vdP$$

Also

$$\partial q_{\text{rev}} = TdS = 0$$

From equation (1)

$$\partial W_{\text{rev}} = vdP$$

Reversible work output

$$\partial W_{\text{rev}} = - \int_1^2 vdP$$

So work input to steady-flow devices such as compressor and pumps is

$$\partial W_{\text{rev,in}} = \int_1^2 vdP$$

5. Ans. (a)

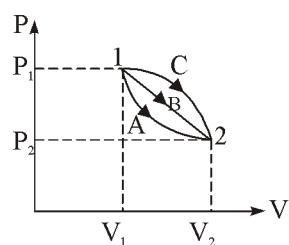
$$W = P_1 V_1 \ln \frac{V_2}{V_1}$$

$$= 800 \times 0.015 \ln \frac{0.030}{0.015}$$

$$= 8.317 \text{ kJ}$$

6. Ans. (d)

Heat and work are path functions



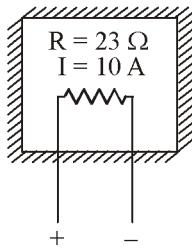
From figure, it is possible to take a system from state 1 to 2 along many quasi-static paths A, B or C.

Since the area under each curve represents the work for each process, the amount of work involved in each case is not a function of end states and it depends on the path system follows in going from state 1 to 2.

7. Ans. (a)

$$\text{Power} = I^2R \\ = 2.3 \text{ kW}$$

$$dQ - dW = dU$$



$$dQ = 0 \text{ (insulated)}$$

dW = negative sign (External Agent)

$$0 - (-P) = dU$$

$$0 - (-2.3) = dU$$

$$dU = 2.3 \text{ kW} \quad (\therefore dQ = 0)$$

$$dW = -2.3 \text{ kW}$$

8. Ans. (d)

$$W = v dp \\ = \frac{1}{\rho} dp = \frac{1}{990} \times (30 - 1) 10^2 \\ = 2.93 \text{ kJ/kg}$$

9. Ans. (a)

Given,

Initial pressure,

$$P_1 = 1 \text{ bar}$$

Final pressure,

$$P_2 = 5 \text{ bar}$$

Initial volume,

$$V_1 = 5 \text{ m}^3$$

$$W = P_1 V_1 \ln \frac{P_1}{P_2}$$

$$W = 10^5 \times 5 \times \ln \left(\frac{5}{1} \right)$$

$$= 804718.95$$

$$= 804.71 \text{ kJ}$$

10. Ans. (b)

For (1-2) process;

Constant pressure process ($P_2 = P_1$)

$$\frac{T_1}{V_1} = \frac{T_2}{V_2}$$

$$V_2 = \frac{T_2}{T_1} \times V_1$$

For (2-3) process;

Constant volume process ($V_3 = V_2$)

Given,

$$T_2 = \frac{3T_1}{4}$$

$$V_2 = \frac{3T_1}{4T_1} \times V_1$$

$$V_2 = \frac{3}{4} V_1$$

Now,

$$\frac{V_2}{V_1} = \frac{3V_1}{4V_1} = \frac{3}{4} = 0.75$$

11. Ans. (c)

$p + \frac{a}{v^2}$ both term should give same unit since they are getting added

$$\frac{N}{m^2} = a \left(\frac{kg}{m^3} \right)^2$$

Unit of (a)

$$\frac{m^6}{kg^2} kg \frac{m}{s^2 \cdot m^2} = \frac{m^5 kg}{kg^2 \cdot s^2} = \frac{m^5}{kg \cdot s^2}$$

12. Ans. (a)

It is sufficient to know only the temperature

13. Ans. (4.50 to 4.60) kg

$$p = \rho gh = 0.7 \times 1360 \times 9.81 \\ = 93.3912 \text{ kPa}$$

Actual pressure = atmospheric pressure + manometric pressure

$$p = 93.39 + 101.325$$

$$p = 194.72 \text{ kPa}$$

Now

$$pv = mRT$$

$$m = \frac{pv}{RT}$$

$$= \frac{194.72 \times 2 \times 28}{288 \times 8.314}$$

$$= 4.55 \text{ kg}$$

14. Ans. (1120 to 1140)K

$$\text{Work} = T \times \theta$$

$$1000 \times 100 \times 2\pi = C_p \Delta T$$

$$\Delta T = 628.3105 \text{ K}$$

$$P_1 V_1 = mRT_1$$

$$10^2 \times 1 = 1 \times 0.2 \times T_1$$

$$T_1 = 500 \text{ K}$$

$$T_2 = 628.31 + 500$$

$$= 1128.31 \text{ K}$$

Work done,

$$W_{1-2} = - \int_{V_1}^{V_2} \left(\frac{C}{V} \right) dV$$

$$= -C \ell n \left(\frac{V_2}{V_1} \right)$$

$$= -mRT \ell n \left(\frac{V_2}{V_1} \right)$$

15. Ans. (b)

16. Ans. (d)

17. Ans. (14 to 16) kJ

Given,

$$P_1 = 100 \text{ kPa}$$

$$P_2 = 200 \text{ kPa}$$

$$V_1 = 0.2 \text{ m}^3$$

$$V_2 = 0.1 \text{ m}^3$$

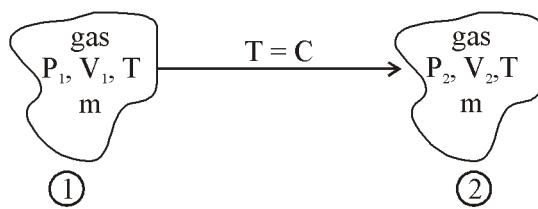
$$R = 0.275 \text{ kJ/kgK}$$

$$W_{1-2} = \frac{1}{2}(P_1 + P_2)(V_1 - V_2)$$

$$= \frac{1}{2}(100 + 200)(0.2 - 0.1)$$

$$W_2 = 15 \text{ kJ}$$

18. Ans. (b)



Applying

$$PV = mRT$$

$$PV = \text{constant} = C$$

19. Ans. (62.5)

W = Area of triangle

$$W = \frac{1}{2}(0.5 \times 250) = 62.5$$

20. Ans. (d)

Apply steady flow energy equation

$$\dot{m} \left[h_1 + \frac{C_1^2}{2} + z_1 g \right] + Q = \dot{m} \left[h_2 + \frac{C_2^2}{2} + z_2 g \right] + W_{in}$$

$$\dot{m} = \frac{P_1 V_1}{R T_1} = \frac{100 \times 15}{0.5 \times 300} = 10 \text{ Kg/S}$$

$$\dot{m} h_1 + Q = \dot{m} h_2 + W_{in}$$

$$10 \times h_1 - 51 = 10 \times h_2 + (-101)$$

$$10[h_2 - h_1] = 101 - 51$$

$$10 \times C_p(T_2 - T_1) = 50$$

$$10 \times 1 \times [T_2 - 300] = 50$$

$$T_2 = 305 \text{ K}$$

$$T_2 = 32^\circ\text{C}$$

