29. Ans (a)

Solution:

For flow to be incompressible

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \text{ (continuity equation)}$$

For flow to be irrotational

$$\frac{\partial^2\psi}{\partial x^2}+\frac{\partial^2\psi}{\partial y^2}=0$$

Checking the given flow in each case:

Case P

$u = 2y,\ v = -3x$

$$\therefore \frac{\partial(2y)}{\partial x}+\frac{\partial(-3x)}{\partial y}=0+0=0 \text{ (incompressible)}$$

Also

$$\frac{\partial y}{\partial x}=v=2y \therefore \frac{\partial^2 y}{dx^2}=0$$

$$\frac{\partial\psi}{\partial y}=-u=3x \therefore \frac{\partial^2\psi}{dy^2}=0$$

$$\therefore \frac{\partial^2\psi}{dx^2}+\frac{\partial^2\psi}{dy^2}=0+0=0 \text{ (irrotational)}$$

Case Q

$u = 3xy,\ v = 0$

$$\frac{\partial(3xy)}{\partial x}+\frac{\partial(0)}{\partial y}=3y+0=3y \text{ (compressible)}$$

Also

$$\frac{\partial y}{\partial x}=v=0 \therefore \frac{\partial^2\psi}{dx^2}=-3x$$

$$\frac{\partial\psi}{\partial y}=-u=-3xy \therefore \frac{\partial^2\psi}{dy^2}=-3x$$

$$\therefore \frac{\partial^2(\psi)}{dx^2}+\frac{\partial^2(\psi)}{2y^2}=0-3x=-3x \text{ (rotational)}$$

Case R

$u = -2x,\ v = 2y$

$$\frac{\partial(-2x)}{2x}+\frac{\partial(2y)}{\partial y}=-2+2=0 \quad \text{(incompressible)}$$

Also

$$\frac{\partial\psi}{\partial x}=2y \therefore \frac{\partial^2\psi}{\partial x^2}=0$$

$$\frac{\partial\psi}{\partial y}=-(-2x) \therefore \frac{\partial^2\psi}{\partial y^2}=0$$

$$\therefore \frac{\partial^2(\psi)}{\partial x^2}+\frac{\partial^2(\psi)}{2y^2}=0+0=0 \text{ (irrotational)}$$

Case P and R are fitting

30. Ans (a)

Solution:

We know, pumping power in kW is; P = ρ, g, Q, h_f

Where

Density $\rho = 1000\ \text{kg/m}^3$

Gravity $g = 9.81\ 14/\text{sec}^2$

Discharge $Q = 0.07\ \text{m}^3/\text{sec}$

Head loss in pipe due to friction

$$h_f=\frac{f\,L\,Q^2}{12D^5}$$

Where

Friction factor $f = 0.02$

Pipe length = 1 km = 1000 m = L

$$\text{Diameter 'D'} = \frac{200}{1000}=0.2\text{ m}$$

$$\therefore h_f=\frac{0.02\times1000\times(0.07)^2}{12\times(0.2)^5}$$

$= 25.52$ m

$\therefore$ P = 1000 × 9.81 × 0.07 × 25.52 W

= 17524.5 W

= 17.52 kW

31. Ans (a)

Solution:

We know, velocity profile in a circular pipe

$$u(r)=u_{max}\left(1-\frac{r^2}{R^2}\right)$$

$$=-\frac{R^2}{4\mu}\left(\frac{dp}{dx}\right) \text{ where } \frac{dp}{dx}=\text{constant}$$

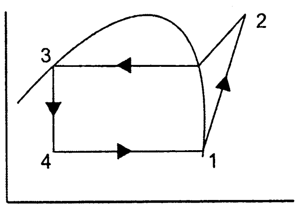
$$\therefore u_{max}=-\frac{R^2}{4\mu}\left(\frac{dp}{dx}\right)$$

$$\therefore u_{avg}=\frac{u_{max}+0}{2}-\frac{R^2}{8\mu}\left(\frac{dp}{dx}\right)$$

6. Nitrogen at an initial state of 10 bar, 1 m^3 and 300 K is expanded isothermally to a final volume of 2 m^3. The p-v-T relation is $\left(p+\frac{a}{v^2}\right)v = RT$, where $a > 0$. The final pressure

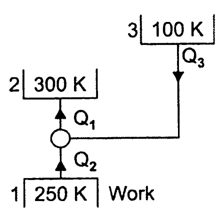
(a) Will be slightly less than 5 bar
(b) Will be slightly more than 5 bar
(c) Will be exactly 5 bar
(d) Cannot be ascertained in the absence of the value of a.

7. The vapour compression refrigeration cycle is represented as shown in figure below, with state 1 being the exit of the evaporator. The coordinate system used in this figure is



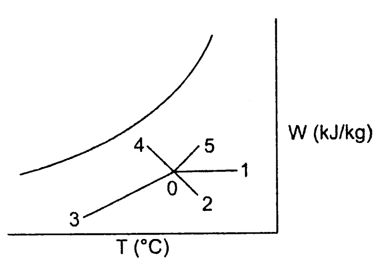
(a) p-h (b) T-s
(c) p-s (d) T-h

8. A vapour absorption refrigeration system is a heat pump with three thermal reservoirs as shown in figure. A refrigeration effect of 100 W is required at 250 K when the heat source available is at 400 K. Heat rejection occurs at 300 K. The minimum value of heat required (in W) is



(a) 167 (b) 100
(c) 80 (d) 20

9. Various psychometric processes are shown in figure below.

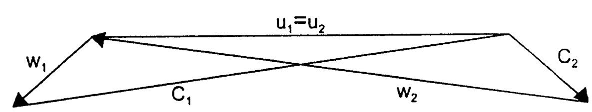


Process in Figure	T (°C)	Name of the process
P.	0–1	1. Chemical dehumidification
Q.	0–2	2. Sensible heating
R.	0–3	3. Cooling and dehumidification
S.	0–4	4. Humidification with steam injection
T.	0–5	5. Humidification with water injection

The matching pairs are

(a) P-l, Q-2, R-3, S-4, T-5
(b) P-2, Q-l, R-3, S-5, T-4
(c) P-2, Q-l, R-3, S-4, T-5
(d) P-3, Q-4, R-5, S-l, T-2

10. In the velocity diagram shown below, u = blade velocity, C = absolute fluid velocity and w = relative velocity of fluid and the subscripts 1 and refer to inlet and outlet.



(a) An impulse turbine
(b) A reaction turbine
(c) A centrifugal compressor
(d) An axial flow compressor

Common Data for Questions 11 and 12

In two air standard cycles—one operating on the Otto and the other on the Brayton cycle—air is isentropically compressed from 300 to 450 K. Heat is added to raise the temperature to 600 K in the Otto cycle and to 550 K in the Brayton cycle.

11. If; η_0 and η_b are the efficiencies of the Otto and Brayton cycles, then

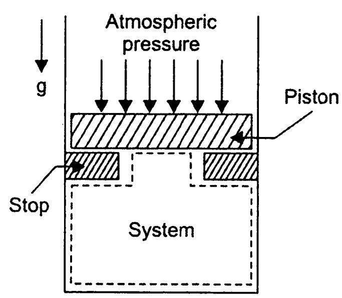
(a) $\eta_0 = 0.25, \eta_B = 0.18$
(b) $\eta_0 = \eta_B = 0.33$
(c) $\eta_0 = 0.5, \eta_B = 0.45$
(d) It is not possible to calculate the efficiencies unless the temperature after the expansion is given

12. If W_0 and W_B are work outputs per unit r

(a) $W_0 > W_B$
(b) $W_0 < W_B$
(c) $W_0 = W_B$
(d) It is not possible to calculate the work unless the temperature after expansions

Common Data for Questions 44, 45 and 46

In the figure shown, the system is a pure substance kept in a piston-cylinder arrangement. The system is initially a two-phase mixture containing 1 kg of liquid and 0.03 kg of vapour at a pressure of 100 kPa. Initially, the piston rests on a set of stops, as shown in figure. A pressure of 200 kPa is required to exactly balance the weight of the piston and the outside atmospheric pressure. Heat transfer takes place into the system until its volume increases by 50%. Heat transfer to the system occurs in such a manner that the piston, when allowed to move, does so in a very slow (quasi-static/quasi-equilibrium) process. The thermal reservoir from which heat is transferred to the system has a temperature of 400°C. Average temperature of the system boundary can be taken as 175°C. The heat transfer to the system is 1 kJ, during which its entropy increases by 10 J/K.



Specific volume of liquid (v_f) and vapour (v_g) phases, as well as values of saturation temperatures are given in the table below.

Pressure (kPa)	Saturation temperature T_{sat} (°C)	v_f(m³/kg)	v_g(m³/kg)
100	100	0.001	0.1
200	200	0.0015	0.002

44. At the end of the process, which one of the following situations will be true?
(a) Superheated vapour will be left in the system
(b) No vapour will be left in the system
(c) A liquid + vapour mixture will be left in the system
(d) The mixture will exist at a dry saturate vapour state

45. The work done by the system during the process is
(a) 0.1 kJ (b) 0.2 kJ
(c) 0.3 kJ (d) 0.4 kJ

46. The net entropy generation (considering the system and the thermal reservoir together) during the process is closest to
(a) 7.5 J/K (b) 7.7 J/K
(c) 8.5 J/K (d) 10 J/K

GATE 2009 — One Mark Questions

47. If a closed system is undergoing an irreversible process, the entropy of the system
(a) Must increase
(b) Always remains constant
(c) Must decrease
(d) Can increase, decrease or remain constant

48. A frictionless piston—cylinder device contains a gas initially at 0.8 MPa and 0.015 m³. It expands quasistatically 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

49. In an ideal vapour compression refrigeration cycle, the specific enthalpy of refrigerant (in kJ/kg) at the following states is given as:
Inlet of condenser: 283
Exit of condenser: 116
Exit of evaporator: 232
The COP of this cycle is
(a) 2.27 (b) 2.75
(c) 3.27 (d) 3.75

50. 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) $\int_1^2 vdp$
(c) $v_1(p_2 - p_1)$ (d) $-p_2(v_1 - v_2)$

GATE 2009 — Two Marks Questions

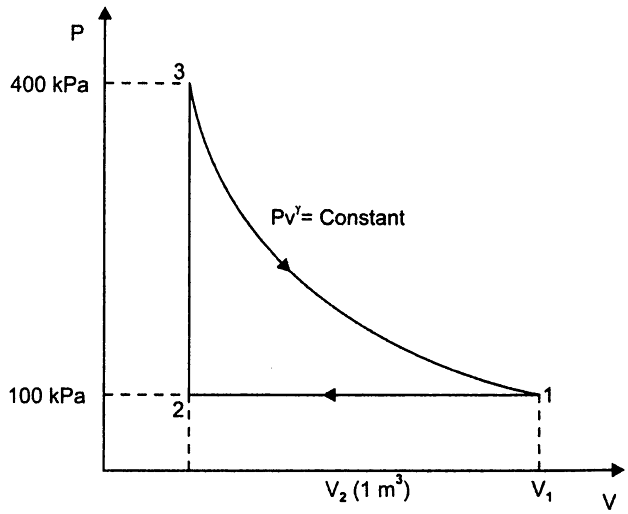
51. In an air-standard Otto cycle, the compression ratio is 10. The condition at the beginning of the compression process is 100 kPa and 27°C. Heat added at constant volume is 1500 kJ/kg, while 700 kJ/kg of heat is rejected during the other constant volume process in the cycle. Specific gas constant for air = 0.287 kJ/kg.K. The mean effective pressure (in kPa) of the cycle is
(a) 103 (b) 310
(c) 515 (d) 1032

32. Ans. (c)

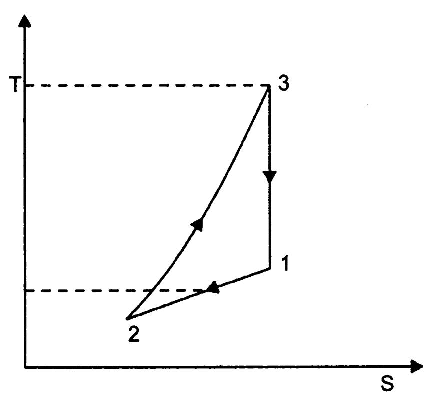
33. Ans. (a)

Solution:

PV diagram (Lenoir cycle)



3–1 is adiabatic process (constant entropy process)
1–2 is isobaric and 2–3 constant volume.
∴ TS diagram (Lenoir cycle)



We know

Air standard efficiency.

For the cycle $\eta_{th} = 1 - \dfrac{r\left(\dfrac{1}{r^{r-1}-1}\right)/(r-1)}{r-1}$

Where, specific heat ratio $r = \dfrac{Cp}{Cv} = 1.4$

Pressure ratio $r = \dfrac{P_3}{P_2} = \dfrac{400}{100} = 4$

$$\therefore\ \eta = 1 - \frac{1.4\left[\dfrac{\dfrac{1}{4^{1.4-1}}}{4-1}\right]}{4-1} \times 1003 = 43.52\%$$

34. Ans. (b)

Solution: We know, change in entropy $\Delta S = \int \frac{\delta Q}{T}$

Since δQ in zero, $\Delta S = 0$

35. Ans. (b)

Solution: The correct statement is "Heat rejection at constant volume–exhaust process."

36. Ans. (c)

Solution: Maximum amount of work that could be utilised from the process.

$$= \int Vdp = 0.01\ (300 - 100) \times 10^3$$
$$= 2 \times 10^3 J = 2\ kJ$$

37. Ans. (a)

Solution: For the process (cyclic device)

$$\frac{\delta Q}{T} = \frac{100 \times 10^3}{1000} + \frac{50 \times 10^3}{500} - \frac{60 \times 10^3}{300} = 0$$

Since $\int \frac{\delta Q}{T} = 0$

The process is reversible and as the heat flows from high temperature to low temperature. It is a heat pump.

38. Ans. (c)

Solution: As we know

Enthalpy = Internal energy + PV; h = u + PV.

Balloon contain ideal gas and kept in vacuum; so kinetic energy will not change and temperature constant, so internal energy is unchanged.

As $\frac{PV}{T}$ = Constant, PV = Constant

∴ Enthalpy also is constant.

39. Ans. (a)

Solution: Air is filled in the tank.

∴ Specific heat ratio $\frac{Cp}{Cv} = v = 1.4$ temperature of air constant

Pressure = 350 + 273 = 623 K and if temperature in tank is T_2.

Than

$Cp \times 623 = Cv \times T_2$

or $\quad T_2 = 623 \times \frac{Cp}{Cv}$

$= 623 \times 1.4$

$= 872.2$ k

$= 599$ °C

∴ Temperature of gas/air is greater than 350°C