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Important Questions *for* GATE 2022

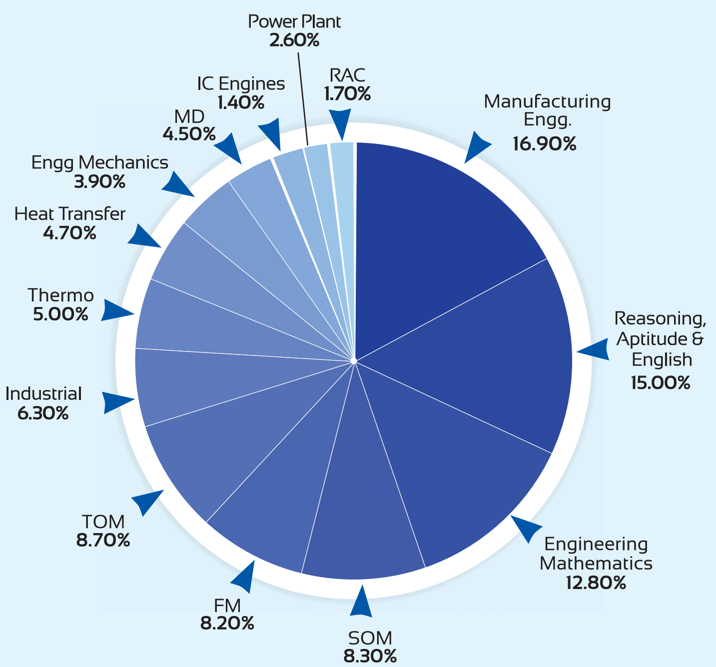
MECHANICAL ENGINEERING

Day 7 of 8

Q.151 - Q.175 (Out of 200 Questions)

Thermodynamics + Engg. Mechanics + Industrial Engg.

SUBJECT-WISE WEIGHTAGE ANALYSIS OF GATE SYLLABUS



Subject	Average % (last 5 yrs)
Manufacturing Engineering	16.90%
Reasoning, Aptitude & English	15.00%
Engineering Mathematics	12.80%
Strength of Materials	8.30%
Theory of Machines	8.70%
Fluid Mechanics & Hydraulic Machines	8.20%
Industrial Engineering	6.30%
Thermodynamics	5.00%
Heat Transfer	4.70%
Engineering Mechanics	3.90%
Machine Design	4.50%
Internal Combustion Engines	1.40%
Power Plant Engineering	2.60%
Refrigeration & Air Conditioning	1.70%
Total	**100%**

Thermodynamics + Engg. Mechanics + Industrial Engg.

Q.151 The specific internal energy of a certain fluid is related as follows:

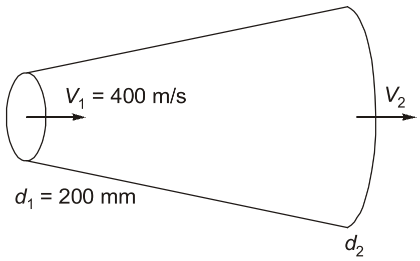
$$u = 196 + 0.718T \text{ kJ/kg}$$

where T is in °C.

A system composed of 2 kg of the this fluid expands in a frictionless piston and cylinder arrangement from an initial state of 1 MPa, 100°C to a final temperature of 30°C. If there is no heat transfer, what is the net work for the process is

(a) 140 kJ (b) – 100.52 kJ
(c) 50.26 kJ (d) 100.52 kJ

Q.152 Air flows through a supersonic adiabatic nozzle as shown in figure. The inlet conditions are 7 kPa and 420°C. The nozzle exit diameter is adjusted such that the exit velocity of air is 700 m/s. The exit diameter of the nozzle is



(a) 151 mm (b) 175 mm
(c) 212 mm (d) 230 mm

Q.153 Two vessels, A and B, each of volume 3 m^3 are be connected together by a tube of negligible volume. Vessel A contains air at 7 bar, 95°C while vessel B contains air at 3.5 bar, 205°C. What is the final temperature of mixing air when vessel A is connected to vessel B? Assume the mixing to be complete and adiabatic.

(a) 402.72 K (b) 375.75 K
(c) 398.56 K (d) 423 K

Q.154 Consider the following statements:

1. The work done during isothermal process for steady flow and non-flow is the same [i.e. $-\int v dp = \int p dv$ for isothermal process]
2. Heat transferred during polytropic process on vapour is same for flow process and non-flow process.
3. Throttling process is work producing irreversible adiabatic leading to increase in entropy of the system.
4. Universal gas constant of a perfect gas increases with increase in molecular weight.

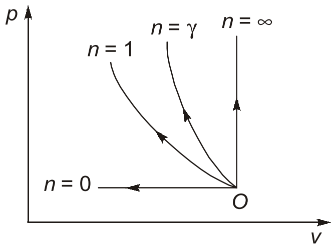
Of these statements

(a) 1 and 2 are true (b) 2 and 3 are true
(c) 2, 3 and 4 are true (d) 1, 2, 3 and 4 are true

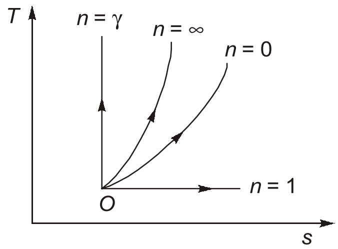
Q.155 A tank fully insulated contains 1 m^3 of air at 50°C and 2 MPa. The valve is open and air escapes until half of the original mass is gone and then the valve is closed. After valve is closed, the pressure inside the tank is

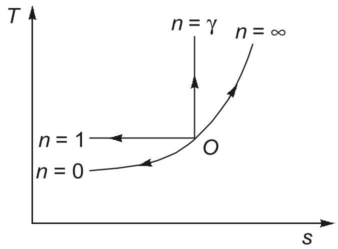
(a) 757.34 kPa
(b) 650 kPa
(c) 1000 kPa
(d) 1200 kPa

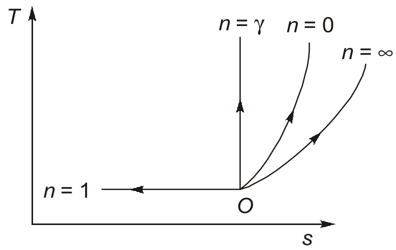
Q.156 Four processes undergone by a perfect gas are shown below in the pressure volume diagram.

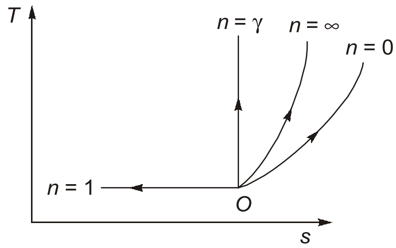


Which representation shows correctly the above processes on T-s diagram?

(a)


(b)


(c)


(d)


Q.157 Air enters a turbine at a pressure of 700 kPa, 65°C with a velocity of 90 m/s and leaves the turbine at 140 kPa, 5°C and 60 m/s velocity. There is no heat transfer from the turbine. Assume air to be an ideal gas with constant specific heat. The second law efficiency of the turbine is _________%. (Assume T_o = 25°C, p_o = 101.325 kPa)

Q.158 For water at 25°C, $\frac{dp_s}{dT_s} = 0.189$ kPa/K (p_s is the saturation pressure in kPa and T_s is the saturation temperature in K) and the specific volume of dry saturated vapour is 43.38 m^3/kg. Assume that the specific volume of liquid is negligible in comparison to that of vapour. Using the Clausius-Clapeyron equation, an estimate of the enthalpy of evaporation of water at 25°C is ___________kJ/kg. [Correct upto two decimal places]

Q.159 Consider the expansion of air through a very small constriction in a pipe from pressure and temperature, of 8 bar and 600 K respectively to pressure of 1.2 bar. Assume air to be an ideal gas. The temperature of surroundings is 25°C. The irreversibility associated with the expansion will be ____________ kJ. [Correct upto 1 decimal place]

Q.160 A body of mass 4 kg and C_p = 2 kJ/kgK is at 500 K. If the atmospheric temperature is 250 K, the maximum work obtainable from the body till it comes to equilibrium with atmosphere is ______ kJ.

Q.161 One kg of air is compressed polytropically from ambient condition (pressure 1 bar and temperature of 300 K) to the pressure of 8 bar and temperature of 600 K. What will be the irreversibility of the process?

Assume, R = 0.287 kJ/kg, c_p = 1.004 kJ/kgK, c_v = 0.716 kJ/kgK.

(a) 6.43 kJ/kg
(b) 12.86 kJ/kg
(c) 8.43 kJ/kg
(d) 10.45 kJ/kg

Q.162 A system is initially at 1200 K and a thermal reservoir at 300 K is available. What will be the maximum amount of work that can be recovered as the system is cooled down to the temperature of the reservoir?

[Heat capacity of the system at constant volume, C_v = 0.05 T^2 J/K^3]

(a) 18.23 MJ
(b) 18.23 kJ
(c) 36.21 kJ
(d) 58.215 J

Q.163 Air initially at 1 bar, 300 K and occupying a volume of 0.18 m^3 undergoes two processes. The air is compressed isothermally until the volume is halved and then undergoes a constant pressure process until the volume is halved again. Assuming ideal gas behaviour, what will be the total work (in kJ) for the two processes?

(a) 51.25
(b) 86.50
(c) 21.47
(d) 42.46

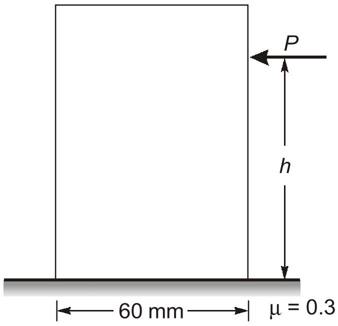
Q.164 Dry saturated steam enters a frictionless adiabatic nozzle with negligible velocity at a temperature of 300°C. It is expanded to a pressure of 5 MPa. The exit velocity of steam will be

Relevant steam table extract is given below

Saturated Temperature (°C)	Saturated Pressure (MPa)	Enthalpy (kJ/kg)		Entropy (kJ/kg °C)		Specific Volume (m^3/kg)	
		h_f	h_g	S_f	S_g	V_f	V_g
300	8.6	1345	2751	3.2552	5.7081	0.0014	0.0216
263.91	5	1154.5	2794.2	2.9206	5.9735	0.0012	0.0394

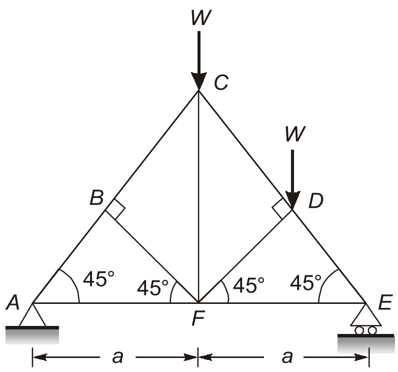
(a) 445.7 m/s
(b) 842.8 m/s
(c) 941.5 m/s
(d) 245.5 m/s

Q.165 A block is of width 60 mm and weight W. A force P is applied to block at height h. Coefficient of friction between block and floor is 0.3. Upto what height h force can be applied so that the block slips without tipping?



(a) 120 mm
(b) 110 mm
(c) 105 mm
(d) 95 mm

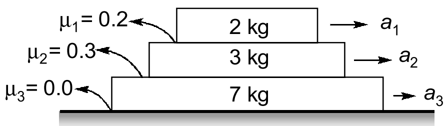
Q.166 A truss $ABCDEF$ carries vertical loads W each at joints C and D. The magnitude and nature of force in member AB is



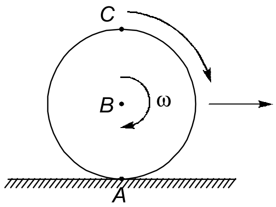
(a) 1.06W (Compressive)
(b) 0.53W (Tensile)
(c) 0.75W (Compressive)
(d) 0.75W (Tensile)

Q.167 The acceleration a_1, a_2, a_3 of the three blocks if a horizontal force of 10 N is applied on 2 kg block will be

(a) $a_1 = 3\text{m/s}^2$, $a_2 = 0$, $a_3 = 0$.
(b) $a_1 = 3\text{m/s}^2$, $a_2 = 0$, $a_3 = 0.57\text{ ms}^2$
(c) $a_1 = 3\text{m/s}^2$, $a_2 = a_3 = 0.4\text{m/s}^2$.
(d) $a_1 = 1.5\text{m/s}^2$, $a_2 = 1.57$, $a_3 = 0\text{ ms}^2$.



Q.168 A sphere is rolling without slipping on a fixed horizontal plane surface. In the figure, A is the point of contact, B is the centre of the sphere and C is its topmost point. Then



(a) $\vec{V}_C - \vec{V}_A = 2(\vec{V}_B - \vec{V}_C)$
(b) $\vec{V}_C - \vec{V}_B = \vec{V}_B - \vec{V}_A$
(c) $2|\vec{V}_C - \vec{V}_A| = 2|\vec{V}_B - \vec{V}_C|$
(d) $|\vec{V}_C - \vec{V}_A| = 4|\vec{V}_B|$

Q.169 A man is standing on a straight bridge over a river and another man is on a boat in the river just below the man on the bridge. If the first man starts walking at the uniform speed of 4 m/min and the boat moves perpendicularly to the bridge at the speed of 5 m/min then the rate at which the boat and man are separating after 4 minutes is _________ m/min. [Assume the height of bridge over the boat is 3 m] [Correct upto 2 decimal places]

Q.170 A news paper boy buys paper for 60 paise each and sells them for ₹ 1.40 each, he cannot return unsold newspaper. Daily demand has the following distribution

Number of customer	Probability
23	0.01
24	0.03
25	0.06
26	0.10
27	0.20
28	0.25
29	0.15
30	0.10
31	0.05
32	0.05

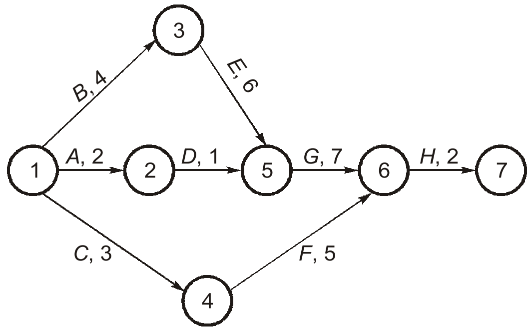
If each day's demand is independent of previous day's, the number of papers ordered each day is ________.

Q.171 A job shop has received an order consisting of 4 different jobs :

Job name	A	B	C	D
Milling Machine	12	8	6	7
Drilling Machine	10	12	14	9

What are the percentage utilization of milling and drilling machines?
(a) 64.71%, 88.24%
(b) 88.24%, 64.71%
(c) 85.46%, 75.63%
(d) 93.45%, 67.75%

Q.172 Consider the following PERT network :



The optimistic time, most likely time and pessimistic time of all the activities are given in the table below:

Activity	Estimated duration		
	Optimistic	Most likely	Pessimistic
A	1	1	7
B	1	4	7
C	2	2	8
D	1	1	1
E	2	5	14
F	2	5	8
G	3	6	15
H	1	2	3

The variance along critical path is

(a) 3.1
(b) 6.1
(c) 9.1
(d) 12.1

Q.173 A repair man is to be hired to repair machines which break down at an average rate of 3 per hour. The breakdown Poisson distribution non-productive time of machine is considered to cost ₹ 16 per hour. Two repair men have been put to work. The slow repairman charges ₹ 8 per hour. The fast repairman demands ₹ 10 per hour and takes 10 minutes to repair a machine. Assuming an 8 hour working day, the total daily cost of the slow repairman exceeds the cost of fast repairman by ₹ 240. The time taken by the slow repairman to repair a machine is __________ minutes.

Multiple Select Questions (MSQ)

Q.174 Which of the following statement(s) is/are correct?

(a) A linear programming problem with three variables and two constraints can be solved by graphical method.

(b) For solutions of a linear programming problem with mixed constraints, Big-M method can be employed.

(c) In the solution process of a linear programming problem using Big-M-method, when an artificial variable leaves the basic, the column of the artificial variable can be removed from all subsequent tables.

(d) All of the above

Q.175 A company has four warehouses and six stores. The warehouses altogether have a surplus of 22 units of a given commodity, divided among them as follows:

Warehouse	1	2	3	4
Surplus	5	6	2	9

The six stores altogether need 22 units the commodity. Individual requirements at stores 1, 2, 3, 4, 5 and 6 are 4, 4, 6, 2, 4 and 2 units respectively.

If x_{ij} represents the number of units of commodity to be shipped from warehouse to store, then which of the following are correct?

(a) $\sum_{j=1}^{5} x_{1j} = 5, \sum_{j=1}^{6} x_{2j} = 6, \sum_{j=1}^{6} x_{3j} = 2$ and $\sum_{j=1}^{6} x_{4j} = 9$

(b) $\sum_{j=1}^{5} x_{1j} = 4, \sum_{j=1}^{6} x_{2j} = 4, \sum_{j=1}^{6} x_{3j} = 6, \sum_{j=1}^{6} x_{4j} = 2, \sum_{j=1}^{6} x_{5j} = 4, \sum_{j=1}^{6} x_{6j} = 2$

(c) $\sum_{i=1}^{4} x_{i1} = 4, \sum_{i=1}^{4} x_{i2} = 4, \sum_{i=1}^{4} x_{i3} = 6, \sum_{i=1}^{4} x_{i4} = 2, \sum_{i=1}^{5} x_{i5} = 4, \sum_{i=1}^{6} x_{i6} = 2$

(d) $\sum_{i=1}^{4} x_{i1} = 5, \sum_{i=1}^{4} x_{i2} = 6, \sum_{i=1}^{4} x_{i3} = 2, \sum_{i=1}^{4} x_{i4} = 9$

■■■■

Detailed Explanations

151. **(d)**

Given data:

$$u = 196 + 0.718T \text{ kJ/kg}$$
$$m = 2 \text{ kg}$$
$$P_1 = 1 \text{ MPa} = 1000 \text{ kPa}$$
$$T_1 = 100°\text{C}$$
$$T_2 = 30°\text{C}$$
$$Q = 0$$

Using first law of thermodynamics for the process,

$$Q = dU + W$$
$$0 = m(u_2 - u_1) + W$$

or
$$-W = m(u_2 - u_1)$$
$$= 2(196 + 0.718T_2 - 196 - 0.718T_1)$$
$$= 2 \times 0.718(T_2 - T_1)$$
$$= 2 \times 0.718 \times (30 - 100)$$
$$-W = -100.52 \text{ kJ}$$

or
$$W = \mathbf{100.52 \text{ kJ}}$$

152. **(c)**

Given data:
$$P_1 = 7 \text{ kPa}$$
$$T_1 = 420°\text{C} = 693 \text{ K}$$
$$V_1 = 400 \text{ m/s}$$
$$V_2 = 700 \text{ m/s}$$
$$d_1 = 200 \text{ mm} = 0.2 \text{ m}$$

Applying steady flow energy equation,

$$\frac{V_1^2}{2} + c_pT_1 = \frac{V_2^2}{2} + c_pT_2$$
$$\frac{(400)^2}{2} + 1005 \times 693 = \frac{(700)^2}{2} + 1005 \times T_2$$
$$80000 + 696465 = 245000 + 1005\,T_2$$
$$T_2 = 528.82 \text{ K}$$

or
$$P_1 = \rho_1 RT_1$$
$$7 = \rho_1 \times 0.287 \times 693$$

or
$$\rho_1 = 0.03519 \text{ kg/m}^3$$

$$\rho_2 = \rho_1\left(\frac{T_2}{T_1}\right)^{\frac{1}{(\gamma-1)}} = 0.03519 \times \left(\frac{528.82}{693}\right)^{\frac{1}{1.4-1}} = 0.0179 \text{ kg/m}^3$$

Applying continuity equation,

$$\rho_1 A_1 V_1 = \rho_2 A_2 V_2$$
$$\rho_1 \times \frac{\pi}{4} d_1^2 V_1 = \rho_2 \times \frac{\pi}{4} d_2^2 \times V_2$$

or $$\rho_1 d_1^2 V_1 = \rho_2 d_2^2 V_2$$

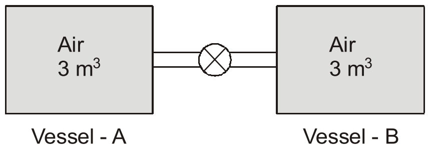
$$0.03519 \times (0.2)^2 \times 400 = 0.0179 \times d_2^2 \times 700$$

or $$d_2^2 = 0.04493$$

or $$d_2 = 0.21196 \text{ m} = 211.96 \text{ mm} \approx 212 \text{ mm}$$

153. (c)

Given data:



$$V_A = V_B = 3 \text{ m}^3$$
$$p_A = 7 \text{ bar} = 700 \text{ kPa}$$
$$T_A = 95°\text{C} = 368 \text{K}$$
$$p_B = 3.5 \text{ bar} = 350 \text{ kPa}$$
$$T_B = 205°\text{C} = 478 \text{ K}$$

Mass of air in vessel A is given by

$$m_A = \frac{p_A V_A}{RT_A} = \frac{700 \times 3}{0.287 \times 368} = 19.88 \text{ kg}$$

Mass of air in vessel B is given by

$$m_B = \frac{p_B V_B}{RT_B} = \frac{350 \times 3}{0.287 \times 478} = 7.65 \text{ kg}$$

Since mixing is adiabatic,

Internal energy before mixing = Internal energy after mixing

$$m_A c_v T_A + m_B c_v T_B = (m_A + m_B) c_v T_f$$

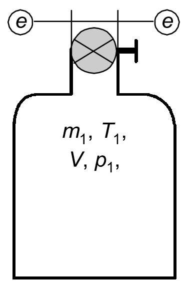
where T_f = Final temperature

or $$T_f = \frac{m_A T_A + m_B T_B}{m_A + m_B} = \frac{19.88 \times 368 + 7.65 \times 478}{19.88 + 7.65} = 398.56 \text{ K}$$

154. (a)

155. (a)

Given data:



$$V = 1 \text{ m}^3$$
$$T_1 = 50°\text{C} = 323 \text{ K}$$
$$p_1 = 2 \text{ MPa} = 2000 \text{ kPa}$$
$$m_2 = 0.5\, m_1$$
$$p_1 V = m_1 R T_1$$
$$2000 \times 1 = m_1 \times 0.287 \times 323$$

or $$m_1 = 21.57 \text{ kg}$$
$$m_2 = 0.5 \times 21.57 = 10.78 \text{ kg}$$
$$m_e = m_1 - m_2 = 21.57 - 10.78 = 10.78 \text{ kg}$$

Applying unsteady flow energy equation,

$$\frac{dU}{dt} = m_i h_i + Q - m_e h_e - W_{cv}$$

$$\text{where} \quad Q = 0 \quad (\because \text{ adiabatic process})$$
$$W_{cv} = 0 \quad (\because \text{ constant volume})$$
$$m_i = 0 \quad (\because \text{ no inlet})$$

$$\frac{dU}{dt} = \frac{dm}{dt} \times h_e$$

$$c_v\left\{T\frac{dm}{dt} + m\frac{dT}{dt}\right\} = \frac{dm}{dt} \times c_p \times T$$

$$T\frac{dm}{dt} + m\frac{dT}{dt} = \frac{dm}{dt} \times \gamma T$$

$$m\frac{dT}{dt} = \frac{dm}{dt} \times (\gamma - 1)T$$

$$\int \frac{dT}{T} = \int\left(\frac{dm}{m}\right) \times (\gamma - 1)$$

$$\ln\frac{T_2}{T_1} = (\gamma - 1)\ln\frac{m_2}{m_1}$$

$$\ln\frac{T_2}{323} = 0.4\ln\frac{1}{2}$$

$$T_2 = 244.788 \text{ K}$$

$$p_2 = \frac{m_2RT_2}{V_2} = \frac{10.78 \times 0.287 \times 244.788}{1} = 757.339 \text{ kPa}$$

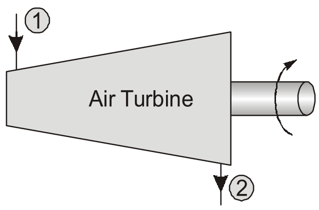
156. (b)

157. (44.03)(43.50 to 44.50)

Given data:

At inlet:

$$p_1 = 700 \text{ kPa}$$
$$T_1 = 65°\text{C} = 338\text{K}$$
$$V_1 = 90 \text{ m/s}$$



At exit:

$$p_2 = 140 \text{ kPa}$$
$$T_2 = 5°\text{C} = 278\text{K}$$
$$V_2 = 60 \text{ m/s}$$
$$T_o = 25°\text{C} = 298\text{K}$$

Maximum work: $$w_{\max} = (h_1 - h_2) - T_o(s_1 - s_2) + \frac{V_1^2 - V_2^2}{2}$$

$$= c_p(T_1 - T_2) - T_o\left(c_p\log_e\frac{T_1}{T_2} - R\log_e\frac{p_1}{p_2}\right) + \frac{V_1^2 - V_2^2}{2000}$$

$$= 1.005(338 - 278) - 298\left(1.005\log_e\frac{338}{278} - 0.287\log_e\frac{700}{140}\right) + \frac{(90)^2 - (60)^2}{2000}$$

$$= 60 - 298(0.1964 - 0.4619) + 2.25 = 141.36 \text{ kJ/kg}$$

Actual work: $$w = (h_1 - h_2) + \frac{V_1^2 - V_2^2}{2}$$

$$= 60 + 2.25 = 62.25 \text{ kJ/kg}$$

Second law efficiency,

$$\eta_{II} = \frac{w}{w_{max}} = \frac{62.25}{141.36} = 0.4403 = 44.03\,\%$$

158. (2443.248) (2443.10 to 2443.45)

At 25°C, $$\frac{dp_s}{dT_s} = 0.189 \text{ kPa/K}$$

Specific volume of saturated vapour,

$$v_s = 43.38 \text{ m}^3\text{/kg}$$

From Clausius-Clapeyron equation neglecting specific volume of liquid

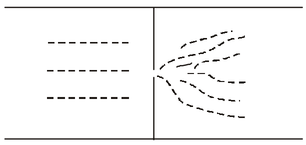
$$\frac{dp_s}{dT_s} = \frac{h_{fg}}{T_s \times v_s}$$

h_{fg} = Enthalpy of vaporization

$$0.189 = \frac{h_{fg}}{(25 + 273) \times 43.38}$$

∴ h_{fg} = **2443.248 kJ/kg**

159. (162.253) (161 to 163)



$$I = T_o\,(\Delta S)_{uni}$$

$$= 298\{s_2 - s_1\} = 298\left\{1.005 \ln\frac{T_2}{T_1} - 0.287 \ln\frac{1.2}{8}\right\}$$

Since it is a free expansion process therefore the temperature will remain constant, therefore $T_2 = T_1$

∴ $$I = -298 \times 0.287 \ln\frac{1.2}{8}$$

$$I = 162.253 \text{ kJ}$$

160. (613.70) (613 to 614)

Maximum work $= \Psi_1 - \Psi_o = (H - T_oS)_1 - (H - T_oS)_o$

$= H_1 - H_o - T_o(S_1 - S_o)$

$$= 4\times 2\times (500-250) - 250\left[4\times 2\times \ln\left(\frac{500}{250}\right)\right]$$

$$= 2000 - 1386.294$$

$$\therefore \quad \Psi_1 - \Psi_o = 613.705 \text{ kJ}$$

161. (b)

$$W_{max} = (u_1 - u_2) - T_o(s_1 - s_2)$$

$$= c_v(T_1 - T_2) - T_o\left(c_p \ln\frac{T_1}{T_2} - R\ln\frac{P_1}{P_2}\right)$$

$$= 0.716(300-600) - 300\left[1.004\ln\frac{300}{600} - 0.287\ln\frac{1}{8}\right]$$

$$= -185.06 \text{ kJ/kg}$$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}$$

$$\Rightarrow \quad \frac{n-1}{n} = \frac{\ln\left(\frac{T_2}{T_1}\right)}{\ln\left(\frac{P_2}{P_1}\right)} = \frac{\ln 2}{\ln 8} = 0.333$$

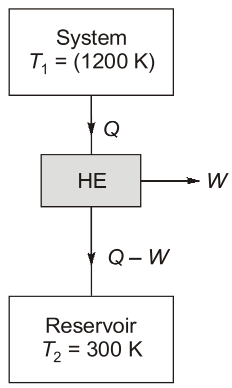
$$\Rightarrow \quad n = 1.5$$

$$W_{actual} = \frac{mR(T_1 - T_2)}{n-1} = \frac{1\times 0.287(300-600)}{1.5-1} = -172.2 \text{ kJ/kg}$$

$$\text{Irreversibility, } I = W_{max} - W_{actual}$$

$$= 185.06 - 172.2 = 12.86 \text{ kJ/kg}$$

162. (a)



Heat removed from the system, $Q_1 = \int_{T_1}^{T_2} C_v dT = \int_{1200}^{300} (0.05T^2)dT$

$$= 0.05\left[\frac{T^3}{3}\right]_{1200}^{300} = -28.35\times 10^6 \text{ J}$$

$$(\Delta s)_{system} = \int_{1200}^{300} \frac{C_v.dT}{T} = \int_{1200}^{300} (0.05\times T^2)\frac{dT}{T}$$

$$= 0.05\int_{1200}^{300} TdT = 0.05\left[\frac{T^2}{2}\right]_{1200}^{300} = -33750 \text{ J/K}$$

$$(\Delta s)_{reservoir} = \frac{Q_1 - W}{T_{Reservoir}} = \frac{28.35\times 10^6 - W}{300} \text{J/K}$$

$$(\Delta s)_{\text{working fluid in HE}} = 0$$

$$(\Delta s)_{\text{universe}} = (\Delta s)_{\text{system}} + (\Delta s)_{\text{reservoir}}$$

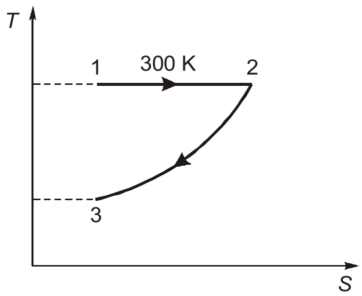
For maximum work, $(\Delta s)_{\text{universe}} = 0$

$$\Rightarrow \quad 0 = -33750 + \frac{28.35 \times 10^6 - W}{300}$$

$$\Rightarrow \quad W = 18.225 \times 10^6 \text{J} = 18.23 \text{ MJ}$$

163. (c)

$$P_1 = 1 \text{ bar}$$
$$T_1 = 300 \text{ K}$$
$$V_1 = 0.18 \text{ m}^3$$
$$V_2 = 0.09 \text{ m}^3$$
$$V_3 = 0.045 \text{ m}^3$$



$$m = \frac{P_1V_1}{RT_1} = \frac{1 \times 10^5 \times 0.18}{287 \times 300} = 0.209 \text{ kg}$$

$$P_2 = \frac{P_1V_1}{V_2} = 2P_1 = 2 \times 1 = 2 \text{ bar}$$

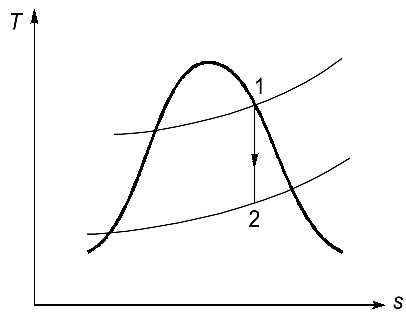
$$W_{1\text{-}3} = W_{1\text{-}2} + W_{2\text{-}3}$$

$$= \int_{V_1}^{V_2} pdv + \int_{V_2}^{V_3} pdv = mRT_1 \ln\frac{V_2}{V_1} + P_2(V_3 - V_2)$$

$$= 0.209 \times 287 \times 300 \times ln\frac{0.09}{0.18} + 2 \times 10^5 (0.045 - 0.09)$$

$$= -21476.6 \text{ J} = -21.476 \text{ kJ}$$

164. (a)



$h_1 = 2751$ kJ/kg $\qquad s_1 = 5.7081$ kJ/kg

Let the dryness fraction at state '2' is x_2.

$$s_1 = s_2 = s_{f_2} + x_2 (s_{g_2} - s_{f_2})$$

$$\Rightarrow \quad x_2 = \frac{S_1 - S_{f2}}{S_{g2} - S_{f2}} = \frac{5.7081 - 2.9206}{5.9735 - 2.9206} = 0.913$$

$$h_2 = h_{f_2} + x_2(h_{g_2} - h_{f_2})$$

$$h_2 = 1154.5 + 0.913(2794.2 - 1154.5) = 2651.65 \text{ kJ/kg.}$$

$$V = 44.72\sqrt{(h_1 - h_2)} = 44.72\sqrt{(2751 - 2651.65)} = 445.7 \text{ m/s}$$

165. (d)

For no tipping or prevent overturning

$$Ph < \frac{Wb}{2}$$

where $W \rightarrow$ weight of block

and $b \rightarrow$ width of block

$$h < \frac{Wb}{2P} \qquad \ldots(1)$$

and for slipping without tipping

$$P > f(\text{force of friction})$$

$$P > \mu W \qquad \ldots(2)$$

From (1) and (2) $\quad h < \dfrac{b}{2\mu}$

$$\therefore \quad h < \frac{60}{0.6}$$

$$\therefore \quad h < 100 \text{ mm}$$

Option (d) is correct.

166. (a)

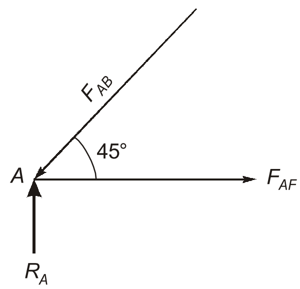
Let Reaction at A be R_A

Taking moments about point E,

$$W \times \frac{a}{2} + Wa = 2a \cdot R_A$$

$$\therefore \quad R_A = 0.75 \text{ W}$$

For equilibrium of joint A,

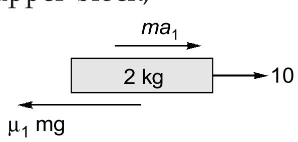


$$F_{AB} \sin 45° = R_A$$

$$F_{AB} = 1.06\,W \text{ (compressive)}$$

167. (c)

Drawing free body diagram of upper block,

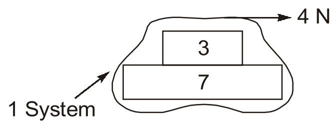


$$10 - \mu_1 mg = m\,a_1$$

$$10 - 0.2 \times 2 \times 10 = 2 \times a_1$$

$$a_1 = 3 \text{ ms}^{-2}$$

For the 3 kg block, as frictional reaction from 2 kg will act towards right, the 3 kg and 7 kg block will move simultaneously, since the 7 kg block is in contact with zero friction surface. There will be no tendency of relative motion between 3 kg and 7 kg and both will move as a same system due to the action of frictional force acting on the top of 3 kg by the 2 kg block



$$4 = 10a$$
$$a = 0.4$$
$$a_2 = 0.4 \text{ ms}^{-2}$$
$$a_3 = 0.4 \text{ ms}^{-2}$$

168. (b)

Let V be the linear velocity and ω is the angular velocity.

$$\vec{V}_C = V + R\omega$$

For pure rolling, $V = R\omega$

$$\vec{V}_C = 2V\hat{i}$$

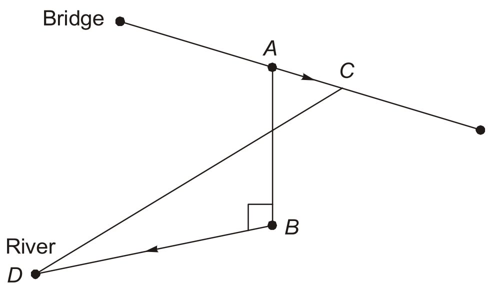
$\therefore$ $$\vec{V}_B = V\hat{i}$$

$$\vec{V}_A = 0$$

$\Rightarrow$ $$\vec{V}_C - \vec{V}_B = 2V\hat{i} - V\hat{i} = V\hat{i}$$

$$\vec{V}_B - \vec{V}_A = V\hat{i} - 0\hat{i} = V\hat{i}$$

169. (6.36) (6.30 to 6.40)



$$\begin{bmatrix} AC \perp AB \perp BD \\ AC \perp ABD \text{ plane} \\ AC \perp AD \end{bmatrix}$$

Initially man was at A and boat was at B. After t minutes, man is at C and boat is at D.

$$AC = 4t, \qquad BD = 5t$$
$$AB = 3 \text{ m}$$
$$DA = \sqrt{AB^2 + BD^2} = \sqrt{3^2 + (5t)^2} = \sqrt{9 + 25t^2}$$

$$DC = \sqrt{AD^2 + AC^2} = \sqrt{9+25t^2+(4t)^2} = \sqrt{9+41t^2}$$

Let the distance between boat and man is

$$x = DC = \sqrt{9+41t^2}$$

$$\frac{dx}{dt} = \frac{1}{2\sqrt{9+41t^2}} \times 41 \times 2t$$

At t = 4 min

$$\frac{dx}{dt} = \frac{41\times 2\times 4}{2\sqrt{9+41\times 4^2}} = 6.36 \text{ m/min}$$

170. (28) (28 to 28)

$$p\,(S-1) < \left(\frac{P}{P+L}\right) \le p(S)$$

$p\,(S-1)$ = Cumulative probability of the demand for $(S-1)$ units.

$p(S)$ = Cumulative probability of the demand for S units.

P = profit /unit

L = loss/unit.

$$\frac{P}{P+L} = \frac{0.8}{0.6+0.8} = 0.57$$

Number of customer	Probability	Cumulative Probability
23	0.01	0.01
24	0.03	0.04
25	0.06	0.10
26	0.10	0.20
27	0.20	0.40
28	0.25	0.65
29	0.15	0.80
30	0.10	0.90
31	0.05	0.95
32	0.05	1.00

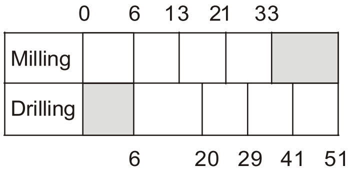
Since $\frac{P}{P+L}$ = 0.57 lies between 0.40 and 0.65.

Hence, optimal number of newspaper to be ordered is 28.

171. (a)

According to Johnson rule, the correct order will be

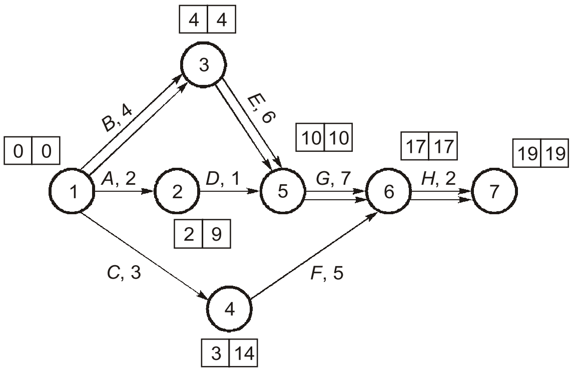
C - D - B - A



Utilisation of milling machine = $\frac{33}{51} \times 100 = 64.71\%$

Utilisation of drilling machine = $\frac{45}{51} \times 100 = 88.24\%$

172. (c)



Critical path : $B - E - G - H$

Critical path duration = 19 days

$$\text{Variance} = \left(\frac{t_p - t_0}{6}\right)^2$$

Activity	t_o	t_m	t_p	Variance
B	1	4	7	1
E	2	5	14	4
G	3	6	15	4
H	1	2	3	0.11

The variance along critical path= 1 + 4 + 4 + 0.11 = 9.11

173. (15) (15 to 15)

Rate of breakdown of machines = λ = 3/hour, Idle time cost of machine = ₹ 16/hour

Fast repairman

$$\text{Rate of repair} = \mu = \frac{1}{10} \times 60/\text{hour} = 6/\text{hour}$$

Average number of breakdown machines in the system = $\frac{\lambda}{\mu - \lambda} = 1$

Machine hours lost in 8 hour day = 1 × 8 = 8 hours

Total cost per day = Cost of idle machines + repairman charges

= ₹(16 × 8 + 10 × 8) = ₹208

⇒ Slow repairman's cost = ₹448

Slow repairman

Slow repairman's daily working charges = ₹ 8 × 8 = ₹ 64

Cost of idle machines = ₹ 448 – ₹64 = ₹384

Number of idle machines a day × cost of idle machine = ₹ 384

Number of idle machines a day × ₹ 16 = ₹ 384

Number of idle machines a day = $\frac{384}{16}$ = 24

Number of idle machines an hour = $\frac{24}{8} = 3$

Average number of breakdown machines in the system

$$= \frac{\lambda}{\mu - \lambda} = \frac{3}{\mu - 3} = 3$$

⇒ μ = 4/ hour

Times taken to repair a machine = 15 minutes

174. **(b, c)**

A LPP with 3 variables and 2 constraints cannot be solved by graphical method.

175. **(a, c)**

Since x_{1j} represents quantity shipped from warehouse to store

The transportation problem is:

C_1	C_2	C_3	C_4	C_5	C_6	5
C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	6
C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	2
C_{19}	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}	9
4	4	6	2	4	2	

where c_1, c_2 .....c_{24} = unit costs of transportation

⇒ $\sum_{j=1}^{6} x_{1j} = 5$ and so on

and $\sum_{i=1}^{4} x_{i1} = 4$ and so on

Option (a) and (c) are correct.

■■■■