MECHANICAL ENGINEERING PAPER I

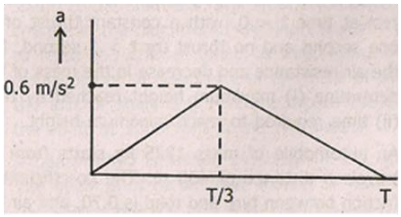
Time allowed: 3 hours **Maximum marks: 300**

INSTRUCTIONS

Each question is printed both in Hindi and in English.
Answers must be written in the, medium specified in the Admission.
Certificate issued to you, which must be stated clearly on the cover of the answer-book in the space provided for the purpose.
No credit will be given for the answers written in a medium other than that specified in the Admission Certificate.
Candidates should attempt Questions **1** *and* **5** *which are compulsory and any* ***THREE*** *of the remaining questions selecting at least* ***ONE*** *question from each Section.*
All questions carry equal marks.
If any data is considered insufficient, assume suitable value and indicate the same clearly.
Newton may be converted to kg using the equality 1 kilonewton (1 kN) = 100 kg, if found necessary.

Section A

1.(a) An elevator starts from rest and raises vertically 40 m to attain its maximum velocity in T seconds, with acceleration record shown in the figure. Determine the time T and the maximum velocity reached by the elevator. 10



(b) For a conventional type 2-stroke cycle four cylinder inline reciprocating engine, sketch the primary and secondary crank diagrams for firing order of I-II-IV-III and find out balancing condition of the engine for primary and secondary effects. 10

(c) Sketch the displacement, velocity and acceleration curves for rise motion alone if the cam-follower is executing uniform and equal acceleration and retardation. State the main disadvantage of this type follower motion. 10

(d) How ductility of structural steel is evaluated from static tension test? What is the effect of gauge length on the value of ductility? 10

(e) A cast iron sample when tested in compression fails along approximately 45° plane from its axis while when tested in torsion also fails along a 45° (approx.) helical plane from its axis. Explain the reason for such failure and mention about the dominating stresses causing failure. 10

(f) Classify stainless steels based on the metallurgical considerations. Write main characteristics of each class of stainless steels. 10

2.(a) A model rocket of mass 0.1 kg is launched vertically from rest at time $t = 0$, with a constant thrust of 10 N for one second and no thrust for $t > 1$ second. Neglecting the air resistance and decrease in the mass of the rocket determine (i) maximum height reached by the rocket, (ii) time required to reach maximum height. 15

(b) An automobile of mass 1225 kg starts from rest, and travels a distance of 400 m. The co-efficient of static friction between tyre and road is 0.70, and air resistance is equivalent to $D = 0.575\ v^2$, where D is in Newton and v is velocity in m/s. The automobile has front wheel drive and front wheel supports 62% of the total weight of

vehicle. Determine the maximum speed reached by the automobile after travelling 400 m distance. 15

(c) Stress concentration factor is not considered harmful for ductile materials in static loading but for brittle materials it has damaging effect in both static and dynamic loading. Justify the above statement giving illustrations. 15

(d) A hollow shaft of outside diameter 50 mm and inside diameter 20 mm is subjected to a torque of T N.m and a bending moment of 0.5 T N.m. If the tensile yield stress of the shaft material is 250 N/mm^2, what is the maximum permissible value of T to avoid failure according to Tresca's failure theory? Take a factor of safety of 2.0 for a given application. 15

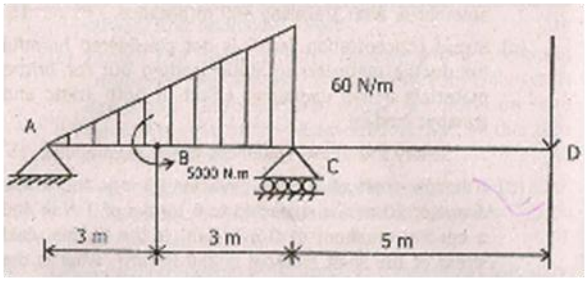
3.(a) A cantilever beam of length L is subjected to two concentrated loads of 2P and P at its mid-length and free end respectively. If deflection at its free end is limited to L/500, what should be the value of P? Take flexural rigidity of the beam as EI. 15

(b) The shaft of a small turbine with a single disc is found to have a static deflection of 0.355 mm. Find the critical speed of the shaft-disc system and calculate percentage change in the diameter of the shaft that will be required to raise the critical speed to 2100 rpm. If the initial displacement of the centre of the mass of the disc from the axis of shaft is 0.5 mm, compare the deflection of the shaft at 1500 rpm in the two cases. 20

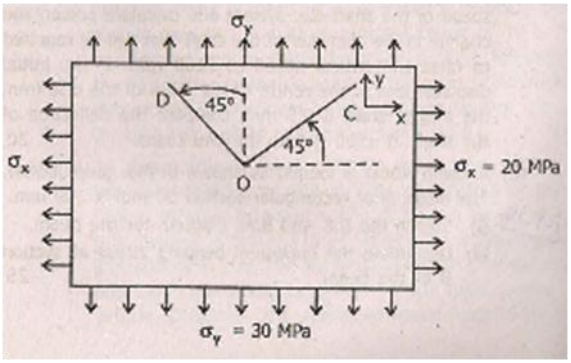
(c) A beam ABCD is loaded as shown in Fig. given below. The beam is of rectangular section 50 mm X 100 mm.

(i) Sketch the S.F. and B.M. diagram for the beam.

(ii) Determine the maximum bending stress at section B of the beam. 25



4.(a) A 1 m x 1 m mild steel sheet of 1 mm thickness is stretched in its own plane by stresses σ_x = 20 MPa and σ_y = 30 MPa as shown in figure below. Point O is centre of the plate. OC and OD are two mutually perpendicular lines inclined at 45° each to *x* and *y* directions respectively before application of stress. Determine the change in angle (in degrees) between OC and OD after application of stresses. Take modulus of rigidity of plate material G = 80 GPa. 20



(b) A simple gear train consists of three spur gears 1, 2 and 3, where gear 1 is the driver, gear 2 idler gear and gear 3 driven gear. The axes of all the 3 gears are in the horizontal

plane. The bearing centers of gears 1, 2 and 3 are designated as A, B and C respectively. Gear 1 has 10 mm module, pressure angle 20° and 35 teeth. Gears 2 and 3 are having 45 teeth and 60 teeth respectively. The driver is rotating at 1000 rpm clockwise and delivers 30 kW of power. Find:

(i) Distance between A and C

(ii) Speed ratio of the gear train.

Draw the free body diagram of the driven gear and show all the forces acting on it. 10

(c) (i) Differentiate between point defects and line defects in a crystalline solid.

(ii) With a neat diagram show two types of line defects. How are they formed? 15

(d) What are ceramic materials? How do they differ from other materials? How are the ceramics toughened? Give one example. 10

Section – B

5.(a) For punching a 10 mm circular hole, and cutting a rectangular blank of 50 x 200 mm from a sheet of 1 mm thickness (mild steel, shear stress = 240 N/mm^2), calculate, in each case: (i) Size of punch (ii) Size of die (iii) Force required. 10

(b) Sketch the international prototype meter. Explain briefly, with reasons, its:

(i) material;

(ii) cross-section;

(iii) support points;

(iv) plane of marking;

(v) environment. 10

(c) Sketch a mould for two hollow components to be cast. On the diagram, indicate runner, gate, riser, core, cope, sprue, pouring basin, sprue well, drag, parting line. 10

(d) An interference assembly, of nominal diameter 20 mm, is of a unilateral holes and a shafts. The manufacturing tolerances for the holes are twice that for the shaft. Permitted interference values are 0.03 to 0.09 mm. Determine the sizes, with limits, for the two mating parts. 10

(e) State the mechanism of cutting by abrasive jet. What are the advantages and disadvantages of AIM? Mention two applications. 10

(f) (i) Identify four major costs associated with poor quality.

(ii) Name the tools for improving quality.

(iii) The operation and their reliabilities of a beauty product are given below:

Operation	Reliability
Mix	0.99
Rll	0.98
Cap	0.99
Label	0.97

What is the reliability of the system?

(g) The feedback from customers shows the following:

Defect	Frequency
Lumps of un-mixed product	7
Over or under filled jars	18
Jar lids did not seal	6
Labels rumpled or missing	29

Draw the Pareto chart to identify vital defects. 10

6.(a) Draw a self explanatory sketch of a Sigma mechanical comparator. Explain how (i) shock load is avoided (ii) oscillations of the pointer are damped. 10

(b) Explain at least two, characteristics each of NC, CNC and DNC. 10

(c) Compare Smith forging, drop forging, press forging and upset forging. Mention three points for each. 10

(d) Determine the optimum speed for achieving maximum production rate in a machining operation. The data is as follows:
Machining time/job = 6 min.
Tool life = 90 min.
Taylor's equation constants C = 100, n = 0.5
Job handling time = 4 min./job
Tool changing time = 9 min. 10

(e) Three process viz. automatic, semi-automatic and manual can be used to produce an item. The initial annual fixed cost and variable cost/unit for each of them is given below:

Process	Annual fixed cost Rs	Variable cost unit Rs
Automatic A	2,50,000	10
Semi-automatic S	1,50,000	20
Manual M	50,000	60

(i) Draw the total annual cost curves for the processes.
(ii) Find the range of production volume for each process when it is most economical.
(iii) Which process will you recommend if the forecasted production is 8000 unit/annum?
(iv) What is the most economic unit cost if the production is 8000 units/annum? 20

7.(a) An activity has four elements. The activity is work-measured and the times (*r*) are recorded on continuous basis over five cycles. The observations are given in table:

Work Element	Observations					Rating Factor
	Cycle →1	2	3	4	5	
1	0.50	3.30	5.70	8.20	10.85	1.1
2	0.70	3.45	5.95	8.55	11.10	1.2
3	1.45	4.05	6.50	9.25	11.75	1.2
4	2.75	5.25	7.60	10.35	13.05	0.8

The time *r* is recorded at the end of work-element.
(i) Calculate:
  (a) Normal time of the activity
  (b) Standard time for the activity, if the allowance is 20%.
(ii) What is the appropriate sample size for estimating the time for element 2 within ± 10% of the true mean with 95% confidence; the standard deviation for the time for element 2 is 0.0742. 30

(b) Draw a self explanatory sketch of oxy-acetylene gas cutting torch. Briefly explain how cutting is effected. 20

(c) In an NC drilling operation, the tool tip is at a location (-100, 0, 100). The datum (0, 0, 0) is left hand lower corner on top surface of the workpiece, which is rectangular (300 mm x 300 mm x 15 mm thick). A thru' hole of 10 mm diameter is to be drilled in the centre of the workpiece. Using only rapid positioning and linear interpolation functions, write the program blocks, in absolute mode.
Assume permitted cutting speed = 32 m/min and feed rate = 150 mm/min. 10

8.(a) Six operators are to be assigned to six machines. Their efficiency on the machines is given in the matrix below:

Operator / Machine	1	2	3	4	5	6
A	0.92	0.95	0.90	0.85	0.75	0.91
B	0.94	0.90	0.88	0.85	0.95	0.93
C	0.75	0.00	0.77	0.70	0.00	0.76
D	0.88	0.85	0.90	0.80	0.85	0.90
E	0.55	0.95	0.90	0.94	0.95	0.90
F	0.50	0.75	0.74	0.80	0.80	0.00

(i) Assign the operators to the machines to maximize overall efficiency.

(ii) State the steps clearly.

(iii) Is there any alternative optimal solution? Justify your answer. 30

(b) What is the principle of electro-chemical machining (ECM)? What are the advantages and disadvantages of ECM over conventional drilling? Comment on the surface finish and the accuracy of the ECM. 20

(c) A seasonal fashion item is to be orders. The acquisition cost is Rs 300 and the selling price is Rs 450. If the salvage value after the season is Rs 150, what should be the order quantity? The probability of demand occurring is known as under:

Demand items	100	110	120	130	140	150
Probability	0.1	0.2	0.2	0.3	0.1	0.1

10

MECHANICAL ENGINEERING PAPER II

Time allowed: 3 hours **Maximum marks: 300**

INSTRUCTIONS

Each question is printed both in Hindi and in English.
Answers must be written in the, medium specified in the Admission.
Certificate issued to you, which must be stated clearly on the cover of the answer-book in the space provided for the purpose.
No credit will be given for the answers written in a medium other than that specified in the Admission Certificate.
Candidates should attempt Questions **1** *and* **5** *which are compulsory and any* ***THREE*** *of the remaining questions selecting at least* ***ONE*** *question from each Section.*
All questions carry equal marks.
If any data is considered insufficient, assume suitable value.
Psychometric chart is attached with this question paper.

Section A

1. Answer the following:

(a) It is desired to maintain a room at temperature of 20°C when outside temperature is 30°C. The volume of this room is 300 m3. The pressure in the room and outside is 1 bar.
  (i) The air in the room is renewed completely in 1 hour. Calculate the mass of air that the air conditioning system pumps into the room.
  (ii) Compute maximum possible CO.P. of this A/C system.
  (iii) When this A/C system is switched off, the temperature inside the room reaches 21°C in 20 minutes. Calculate the amount of heat transferred from the surroundings to the room.
  (iv) Calculate power required by this system. 15

(b) Air is contained in a piston-cylinder arrangement initially at 1.2 bar and 300 K with a volume of 0.12 m^3. Energy as heat of 11.82 Joule is transferred to the air in a quasi-equilibrium constant pressure process to yield a final temperature of 370.2 K. The piston moves without friction. Taking C_p = 1.005 kJ/kg and C_v = 0.72 kJ/kg K, determine the availability change for the process. The reference environment is at 298 K and 1.0135 bar. 15

(c) Sunlight of 1 kW/m^2 falls directly on a window which is a vertical sheet of plain glass. Sun is in south-west and 30° above horizon. Window points towards the south. Estimate the amount of solar energy that,
  (i) enters the building through the window,
  (ii) Is reflected by the window. 15

  Given black body emissivity power table:

λT	F(λT)
1900	0.05210
2000	0.06672
2100	0.08305
15000	0.96893
16000	0.97377
17000	0.97765

(d) Draw rotor and stator blades and velocity diagrams for an axial flow compressor stage and derive the expression for energy transfer in terms of blade speed U, axial velocity

C_a and blade angles. Discuss the effect of variation of axial velocity along blade height on energy transfer. How the influence is taken into account? 15

2.(a) An energy using 10 moles of diatomic ideal gas works on the reversible cycle having the following processes:

(i) Adiabatic compression from 1 bar pressure and 300 K temperature to pressure of 9 times the initial value,

(ii) Constant pressure transformation upto temperature of 1000 K,

(iii) Adiabatic expansion upto 3 bars,

(iv) Constant pressure transformation such that temperature of 1000 K is reached,

(v) Adiabatic expansion,

(vi) Constant pressure transformation upto the original state.

For this engine,

(a) Represent the cycle on a p-v diagram.

(b) Calculate pressure, temperature and volume at salient points.

(c) Calculate the efficiency of the engine summarizing results in a tabular form.

(d) Compare the efficiency of the engine operating on Carnot cycle between the same extreme temperatures. Give comments. 30

(b) Steam enters a nozzle operating at steady state at 40 bars, and 400°C and 10 m/s. Steam flows through this nozzle with negligible heat transfer and change in potential energy. Steam exits at 15 bars and 665 m/s. Mass flow rate is 2 kg/s. Compute exit area of the nozzle.

Given data for steam at 15 bar:

T(°C)	h (kJ/kg)	v (m^3/kg)
250	2023.9	0.15201
300	3038.2	0.16971

and Enthalpy of steam at inlet 3214.5 kJ/kg. 20

(c) What do you understand by governing of steam turbine?

Explain the principle and working of throttle governing with the aid of a neat sketch. Compare the throttle governing with nozzle control governing with following aspects: (i) losses, (ii) use.

Sketch the efficiency against load with throttle governing. 10

3.(a) Water enters a tube of dia D and length L. Inlet and outlet temperature are T_1 and T_2 respectively and wall temperature is T_0. Convective heat transfer is h.

(i) Derive the following expression for heat transfer:

$$Q = \frac{h\pi DL(T_1 - T_2)}{ln\left(\frac{T_1 - T_0}{T_2 - T_0}\right)}$$

(ii) What is the significance of the logarithmic term in part (i) above?

(iii) State assumptions used in part (i). 20

(b) Air is supplied to a convergent-divergent nozzle with a static temperature of 300 K, static pressure of 5 bar and a velocity of 150 m/s. The inlet area of the nozzle is 10 cm^2. A normal shock occurs at a section of the nozzle where flow Mach number is 2. The flow Mach number downstream of shock corresponding to Mach number 2 is 0.577. The flow Mach number at the exit of the nozzle is 0.4. Considering isentropic flow before and after shock and using isentropic flow relation for A/A* and Mach number provided below, find:

(i) Throat area of the nozzle
(ii) area of the nozzle where shock occurs
(iii) exit area of the nozzle
(iv) Loss of stagnation pressure across shock.

Sketch the variation of pressure and Mach number along the length of the nozzle: 30

M	2	0.577	0.4
A/A*	1.688	1.22	1.59

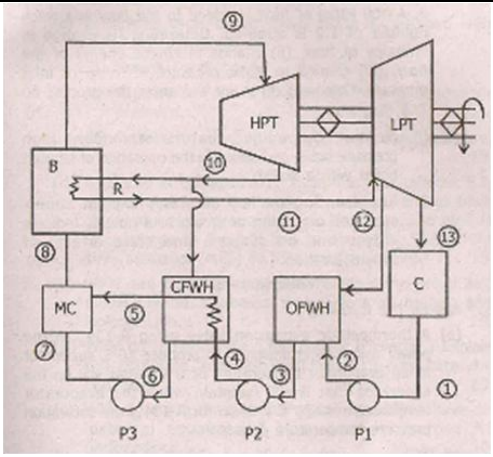
(c) State the factor affecting the amount of draught produced in the boiler and discuss merits and demerits of induced draught system with reference to: (i) boiler efficiency, (ii) fan maintenance, (iii) power to drive the fan, (iv) leakages. 10

4.(a) A steam power plant runs on an ideal reheat-regenerative-Rankine cycle. Details are given in Figure. Steam at turbine inlet is at 150 bars and 600°C. Condenser pressure is 0.10 bar. Steam exiting the HPT is at 40 bars. This steam is split in two parts, y and x. Part x is reheated at the same pressure to 600°C and sent to LPT. Part *y* is condensed completely in CFWH and it is pumped to 150 bars before it mixes with the flow at same pressure. A fraction of steam, z, is extracted from LPT at 5 bars. Assume steam output of boiler as 1 kg/s for ease of computations. Determine:

(i) fraction *y*
(ii) fraction *z*

Given data is:

h_1 = 191.81 kJ/kg	h_9 = 3155.0 kJ/kg
h_2 = 192.3 kJ/kg	h_{10} = 3155.0 kJ/kg
h_3 = 640.09 kJ/kg	h_{11} = 3674.9 kJ/kg
h_4 = 643.02 kJ/kg	h_{12} = 3014.8 kJ/kg
h_5 = 1087.4 kJ/kg	h_{13} = 2335.7 kJ/kg
h_6 = 1087.4 kJ/kg	w_{pump1} = 0.49 kJ/kg
h_7 = 1101.2 kJ/kg	w_{pump2} = 3.83 W/kg
h_8 = 1089.8 kJ/kg	w_{pump3} = 13.77 kJ/kg



R	:	Reheater	B	:	Boiler
HPT	:	High pressure turbine	LPT	:	Low pressure turbine
C	:	Condenser	OFWH	:	Open feedwater heater
CFWH	:	Closed feedwater heater	MC	:	Mixing chamber
P1	:	Pump 1	P2	:	Pump 2
P3	:	Pump 3			

Fig. 1 Schematic of steam power plant 30

(b) Air-flow is entering to a frictionless duct of 0.3 m diameter at a velocity of 580 m/s and a Mach number of 2. A 100 kJ/kg of heat is added to the flow and Mach number of 1.2 is attained. Determine (i) change in enthalpy of flow, (ii) change in kinetic energy of the flow, (iii) change in static pressure in terms of inlet pressure. Comment on result and show the process on T-φ diagram. 20

(c) (i) Mention the unique feature of modern high pressure boiler and describe the operation of Lamont boiler with a sketch.

(ii) Representing on h-φ diagram, explain super-saturated expansion of steam in a nozzle. Indicate Wilson line on diagram and state effects of super-saturation. 10

Section – B

5. Answer the following:

(a) A thermostatic expansion valve using R-134a in the power assembly is designed to produce 10°C superheat at an evaporator temperature of 0°C. What will be the superheat that it will maintain when the evaporator temperature is -30°C? Given for R-134a, the saturation pressure temperature data: 15

Temp (°C)	-30	-25	-20	-15	-10
Pressure (bar)	0.8438	1.065	1.327	1.64	2.006
Temp (°C)	-5	0	5	10	
Pressure (bar)	2.43	2.928	3.5	4.146	

(b) Cold water bottles kept in a room often start condensing atmospheric moisture. What is the minimum temperature to which water bottle can be cooled without any dripping of moisture from its surface when kept in a room at 25°C. DBT and 60% RH? If it is desired that a water bottle at 10°C should also not condense moisture on its surface, what should be the RH in the room keeping the DBT the same? 15

(c) A Rankine cycle based power plant is designed with superheat and reheat:

(i) Sketch T-s diagram.

(ii) Explain the effect of lowering/raising condenser pressure.

(iii) Explain the effect of lowering/raising boiler pressure. 15

(d) A taxicab is equipped with a flexible four cylinder S.I. engine running on a mixture of methanol and gasoline at an equivalence ratio of 0.95. How must the air-fuel ratio change as the fuel flow to the engine shifts from 10% methanol (M10) to 85% methanol (M85)? 15

6.(a) What are the main pollutants emitted by petrol and diesel engine? Discuss their effect on human and biological life. 20

(b) What do you understand by catalytic converter? Explain the principle and the working of 3-way catalytic converter. 20

(c) Why do some thermostatic expansion valves have an 'external equalizer'? How does it improve its performance. 20

7.(a) (i) Explain the phenomena of knocking in S.I. engine. Discuss the effects of following factors on the knocking tendency of S.I. engine:

(1) Compression ratio

(2) Spark tuning

(3) Engine speed

(4) Air-Fuel Ratio

(ii) What are the functions of an additive? Discuss different type of additives and their effect on the properties of lubricating oil. How the lubricating oils are graded as per SAE?

(iii) What are the important points that should be borne in mind when considering the new combustion chamber design? What are the different types of combustion chamber used in C.I. engine? Discuss them in detail with specific advantages and disadvantages and show $dp/d\theta$ for different combustion chambers. 30

(b) In a winter heating air conditioning system 1 kg/s of ambient air at 7°C DBT, 80% RH is sensibly heated, then adiabatically saturated to a high humidity of RH - 90%, and then further sensibly heated to the desired outlet state of 25°C DBT and 50% RH. Determine the temperature of air at various state points and show all the processes on a psychometric chart. Also determine the amount of moisture added per hour in the adiabatic saturator. 30

8.(a) The following data related to a boiler using induced draught system:

Length of the duct carrying flue gas = 150 m
Mean size of the square dust = 75 cm^2
Mean flue gas velocity in the duct = 900 m/min
Mean temperature of gases passing through duct = 227°C
Plenum pressure = 15 cm of water
Atmospheric pressure = 75 cm of Hg
Number of 90° bends = 4
Number of 45° bends = 4
Loss of draft in every 90° bend = 0.1 cm of water
Draft available from chimney 1.5 cm of water
Fuel bed resistance for undefined stoker = 10 cm of water
Fan efficiency = 60 %
Motor efficiency driving fan = 92.5%
Characteristic gas constant for gases = 294 kJ/kg-K
Friction factor, f, corresponding to round section duct 0.006
Assuming that a 45° bend equal one-half of 90° bend and that the resistance offered by square duct is 20% greater than similar round duct, determine:

(i) Draft to be produced due to friction in square cross-section duct in mm of water.
(ii) Draft due to velocity head of flue gases in mm of water.
(iii) Total draft for the boiler.
(iv) Draft to be produced by induced fan.
(v) Power required to drive fan. 30

(b) During a trial of a single cylinder, 4 stroke diesel engine the following observations were recorded:

Bore = 340 mm
Stroke = 440 mm
rpm = 400
Area of indicator diagram = 465 mm^2
Length of diagram = 60 mm
Spring constant = 0.6 bar/mm
Load on hydraulic dynamometer = 950 N
Dynamometer constant = 7460

Fuel used = 10.6 kg/h
Calorific value of fuel (C) = 49500 kJ/kg
Cooling water circulated = 25 kg/min
Rise in temp, of cooling water =25°C
Mass analysis of fuel:
Carbon = 84%
Hydrogen =15%
Incombustible =1%
Volume analysis of exhaust gas:
Carbon dioxide = 9 %
Oxygen =10%
Temp, of Exhaust gases = 400°C
Sp. heat of exhaust gas =1.05kJ/kg°C
Partial pressure of steam in exhaust gas = 0.030 bar
Sp. heat of superheated steam =2.1kJ/kg °C
Saturation temp, of steam at 0.030 bar = 24.1°C
Draw up heat balance sheet on minute basis. 30