MECHANICAL ENGINEERING

PAPER - I

SECTION A

1. Answer any four of the following (each answer should conform to a limit of around 150 words):

(a) "Two balancing masses in two planes are sufficient to produce complete dynamic balance". Justify this statement suitably.

(10)

(b) Explain why undercutting is done to avoid interference of an in volute teeth. Discuss, briefly, the various methods for avoiding undercutting in gear teeth.

(10)

(c) What are dislocations in the structure of solids? Name and graphically represent the two major types of these defects. Indicate how they promote early failure of metals. How is it possible to produce metals free from these defects?

(10)

(d) What assumptions are made, while deriving the equations for stresses in a pressure vessel? Draw the variation of radial and hoop stresses in a thick pressure vessel when it is subjected to (i) internal pressure only (ii) external pressure only.

(10)

(e) Discuss the general features of Shear Force and Bending Moment diagrams in case of simply supported beams to which various types of loads are applied.

(10)

2. (a) A machine punching 4.0 cm diameter holes in 3.1 cm thick plate does 65 kg-m of work per sq. cm. of the sheared area. The punch has a stroke of 10.6 cm and punches 8 holes per minute. The maximum speed of flywheel at its radius of gyration is 29.5 m/sec. Find the weight of the fly/wheel so that its speed does not fall below 90%.Also calculate the H.P. of motor driving the machine.

(15)

(b) A simply supported beam of span '*l*' carries a point load W at the midspan. Design the shape of the beam for uniform strength if (i) width is maintained constant (ii) the depth is kept constant.

(15)

(c) A shaft of uniform circular section is subjected to torsion. Determine the ratio of requisite diameters according to maximum shear stress theory and maximum normal stress theory.

(10)

3. (a) A carriage weighing 6000 kg and moving with a speed of 1 m/sec is brought to rest by a buffer. The buffer consists of a number of rings made out of a wire of 24 mm diameter. Each spring is of mean diameter of 12 cm and has 18 coils. Determine the number of springs required so that their compression in bringing the carriage to rest does not exceed 10 cm. Take $C = 0.84 \times 10^4$ kg/sq. cm.

(16)

(b) Two long columns, which are made of same material, are of equal length. Both are fixed at the ends. One of the columns is of circular section while the other is of square section, the cross-sectional area of the two being equal. Compare the crippling strength of the two.

(12)

(c) What is the significance of Iron-Carbon equilibrium diagram? What information is provided by it for a designer? Sketch a simple iron-carbon diagram showing the important features.

(12)

4. (a) Prove the following from the geometry of the Mohr's circle, σ_1, and σ_2 being the principal stresses:

(i) On the plane of maximum shear stress, the normal and resultant stress components are given by

$$\frac{\sigma_1 + \sigma_2}{2} \text{ and } \sqrt{\frac{\sigma_1^2 + \sigma_2^2}{2}} \text{ respectively.}$$

(ii) The maximum obliquity ϕ of the resultant stress with normal to plane is given by

$$\sin\phi = \frac{\sigma_1 - \sigma_2}{\sigma_1 + \sigma_2}$$

(12)

(b) In a flat belt, the initial tension is 170 kg and the angle of lap on the smaller pulley is 170°. The coefficient of friction between the belt and pulley surface is 0.26. Diameter of the pulley is 85 cm and it runs at 600 rpm. Neglecting the centrifugal tension, determine the power that can be transmitted at the above speed.

(12)

(c) Illustrate the use of discs of uniform strength in industry. Derive an expression for the profile of disc of uniform strength. How does it differ from those for disc of uniform thickness?

(16)

SECTION - B

5. Answer any four of the following each answer should conform to a limit of around 150 words):

(a) What is selective management like ABC analysis? Name and explain 3 such approaches presenting the basis on which they subgroup activities. How this improves management productivity?

(20)

(b) A one mm through hole is to be produced through a glass plate of 3 mm thick (non-conducting material). Suggest the most appropriate recent machining method. Explain with a simple diagram its principle, equipment and operation. What are its capabilities and limitations?

(10)

(c) What is Hi-E range in machining economics? Why is it called this way? How do you establish this range when simple tool-life equation is the only constraint?

(10)

(d) Explain briefly

(i) Profile to learning

(ii) High Energy rate forming

(iii) TQM.

(10)

(e) How does a flow chart help in writing a computer software? Draw a flow chart indicating the various steps for calculating the torsional and bending stresses in a shaft transmitting power.

(10)

6. (a) During orthogonal turning of a steel rod at a feed rate of 0.2 mm/rev, and depth of cut 3 mm by a tool with side rake angle of 10° following observations were made:

Tangential force	-1.80 kgf
Axial force Chip thickness	-90 kgf
Chip thickness	- 0.6 mm

(i) Sketch the Merchant's circle diagram of forces (need not be to scale) showing all the forces concerned.

(ii) Determine by calculation shear angle, shear strain and shear force.

(7 + 8 = 15)

(b) Following data relate to the operating costs of 2 possible locations for a manufacturing plant:

	Location 1	Location 2
Fixed cost (Rs)	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

(i) Which location would minimize the total costs, given an annual production of 50,000 units.

(ii) What is the break even between the locations.

(6 + 6 = 12)

(c) (i) Sample size when attributes of products are inspected is usually larger than when variables are inspected to have the same confidence level - why?

(ii) Twenty samples were taken from a cable weaving machine while it was operated under closely controlled conditions. The number of defects per 100 meters of the samples were recorded in the chart below. Determine the control chart upper and lower limits for the machine. Sketch the same.

4	4	5	3
6	2	2	4
5	3	4	2
3	2	4	5
5	7	5	3

(4 + 9 = 13)

7. (a) Turning operation is performed with the following tool geometry and cutting conditions:

Major cutting edge angle — 60°

(approach angle)

Minor cutting edge angle — 10°

rake angle — 0°

cutting speed — 100RPM

feed — 0.3 mm/rev

depth of cut — 3 mm

What is the roughness height generated? What is its R_a value? If the tool is ground to a nose radius of 2 mm how much is the reduction in roughness height? Derive the relations used.

(13)

(b) A ladies fashion shop wishes to purchase the following quantities of summer dresses:

Dresses	I	II	III	IV
Quantity	200	400	800	300

Three manufacturers are willing to supply dresses. The quantities given below are the maximum they are able to supply to any given combinations of order of dresses.

Manufacturer	A	B	C
Total Quantity	300	900	500

The shop expects the profit per dress to vary with the manufacturers given ahead:

	Sizes			
Manufacturer	I	II	III	IV
A	25	40	50	20
B	30	35	55	15
C	20	45	45	25

(i) Use the transportation algorithm to solve the problem of how the orders should be placed on the manufacturers by the fashion shop to maximize its profits.

(ii) Explain how you know that there is no further improvement possible. Show your workings.

(iii) What is North-west corner rule?

(8 + 5 + 2 = 15)

(c) A furniture refinishers has five items of furniture to sand and varnish the next day. The times for these two operations are shown below, Design the sequence that will minimize the time from the beginning of the first item until the finish of the last (i.e. minimize the flow time).

Item	*Sanding Time (Hours)*	*Varnishing Time (hours)*
A	4.5	2.5
B	4.0	4.5
C	2.0	4.0
D	5.0	4.0
E	3.5	3.5

Prepare the Gantt chart showing the utilization of work stations.

(12)

8. (a) (i) How many degrees of freedom of a job is to be prevented by locators in a fixture?

(ii) What is the principle by which they are to be distributed between faces?

(iii) How many degrees of freedom of a cylinder, a V-locator prevents?

(iv) If two holes of different sizes, like in a connecting rod are used for location for further operations, what shapes of locators are to be used for each hole and why? (If tilting is to be minimized)

(3 + 3 + 3 + 3 = 12)

(b) The results of machining steel with two grades of tool materials are given below:

Tool	Taylor's Exponent	Cutting speed for 1 (one) minute tool life m/s/min/min
A	0.20	100
B	0.25	120

(i) For a 100 minute tool life, which tool is recommended and why?

(ii) If the tool changing time for the preferred tool is 15 minutes which cutting speed has to be chosen from the available speeds 45 m/min; 5 m/min.

(7 + 7 = 14)

(c) (i) What are the commonalities and basic differences between PERT and CPM?

(ii) A product development project consists of the following activities, with their timing and precedents:

Activity	*Designation*	*Immediate Precedents*	*Time in Weeks*
Design	A		21
Build Prototype	B	A	5
Evaluate Equipment	C	A	7
Test Prototype	D	B	2
Write equipment report	E	C,D	5
Write method Report	F	C,D	8
Write final report and release for manufacture	G	E,F	2

Represent the projects as a network diagram in the CPM format. Identify the critical path and project completion time. Calculate the earliest and latest starting and completion time of activity 'E'.

(4 + 10 = 14)

MECHANICAL ENGINEERING

PAPER - II

SECTION A

1. Answer any four parts:

(a) An insulated rigid chamber of 2.5 m^3 capacity contains air at 25 °C and 250 kPa. A paddle wheel inserted in the chamber does 900 kJ of work on the air.

Assuming constant specific heats, calculate the entropy increase during the process. Take C_v = 0.717 kJ/kg-K and R = 0.287 kJ/kg K.

(10)

(b) 3 kg of gas initially at 2.5 bar and 400 K receives 600 kJ of heat under constant volume process from a source at a temperature of 1200 K. If the surrounding temperature is 290 K, find the loss in available energy due to the heat transfer process. Assume C_v 0.81 kJ/kg-K for gas.

(10)

(c) Using Maxwell's equation, derive the following expression for variation of specific heat at constant pressure in an isothermal process:

$$\left(\frac{\partial C_p}{\partial P}\right)_T = -T\left(\frac{\partial^2 V}{\partial T^2}\right)_P$$

Hence show that for an ideal gas C_p is a function of temperature alone.

(10)

(d) State the functions of the following parts of the carburettor: (10)

(i) Venturi

(ii) Float chamber

(iii) Idling jet

(iv) Acceleration jet

(v) Throttle

(e) With the help of neat sketches, explain the working of 2-stroke and 4-strokecycle SI engines. Compare them with regard to (i) power to weight ratio, (ii) thermal efficiency and (iii) practical applications.

(10)

2. (a) Derive the Clapeyron equation in the form

$$h_{fg} = Tv_{fg}\left(\frac{\partial P}{\partial T}\right)$$

where the symbols have their usual meanings. State the application of this equation. (10)

(b) Using Clapeyron equation, predict the enthalpy of evaporation of steam at 200°C. assuming steam to be an ideal gas with R = 0.462 kJ/kg-K.

(10)

(c) A 3 cm outer diameter steam pipe is to he covered with two layers of insulations, each having a thickness of 2.5 cm. The average thermal conductivity of one material is 5 times that of the other. Determine the per cent change in heat transfer if better insulating material is next to pipe than when it is in the outer layer. Assume that the outside and inside surface temperatures of the composite insulation are fixed.

(20)

3. (a) A shell and tube heat exchanger is to be designed to heat 2.5 kg/s of water from 15°C to 85°C. Heating is done by passing hot oil available at 160°C through the shell side of the counterblow heat exchanger. The oil has an average convective coefficient of 400 W/m^2-K on the outer side of the tubes. Ten thin walled tubes, each of 25 mm diameter and making 8 numbers of passes through the shell carry water to be heated. If the oil leaves the exchanger at 100 °C, what is its flow rate? What should be length of tubes in each pass? Take correction factor for LMTD as 0.85. Use the equation.

$$Nu = 0.023\,(Re)^{0.8}\,(Pr)^{0.4}$$

to estimate the heat transfer coefficient for turbulent flow of fluid through tubes.

Assume following properties of fluids:

Oil: C_p = 2.35 kJ/kg-K

Water: C 4.181 kJ/kg-K, Pr = 3.56,

K= 0.643 W/m-K, $\mu = 5.48 \times 10^{-4}$ Pa-s

(30)

(b) Answer the following questions briefly:

(i) Give names of any two primary and two secondary refrigerants.

(ii) Write the chemical formulae for R_{134} and R_{71} refrigerants.

(iii) Why is the evaporator pressure kept above the atmospheric pressure?

(iv) What is meant by eco-friendly refrigerant?

(v) What is halide torch used for?

(10)

4. During a 20-minute trial on a single-cylinder, four-stroke cycle gas engine working on hit-and-miss governing and having bore 20cm and stroke 22 cm, running at 360 r.p.m., following observations were made:

Meaneffeetive pressure (indicated) = 5.2 bar

Total number of explosions = 3500

Net load on brake drum = 42kg

Brake drum diameter = 1 m

Diameter of rope = 4 cm

Total gas consumed = 2.3 m^3 at NTP

Calorific value of the gas = 19,500 kJ/m^3 at NTP

Air consumption at 730 mm Hg and 20°C = 24 m^3

Exhaust gas temperature = 420 °C

Sp. heat of exh. gases at const. pressure =1.015 kJ/kg-K

Cooling water circulation rate = 2.8 kg/mm

Rise in temperature of cooling water = 35°C

Ambient temperature = 25 °C

Calculate-

(i) brake power in kW;

(ii) brake thermal efficiency;

(iii) indicated thermal efficiency;

(iv) mechanical efficiency.

Draw a heat balance sheet on minute basis as well as percentage basis.

Density of air at NTP = 1.29 kg/m^3

R for gas may be assumed as 287 J/kg-K.

NTP is 0 °C and 760 mm of Hg pressure.

(40)

SECTION B

5. Answer any four parts:

(a) Sketch Raleigh line on temperature- entropy plane and clearly show the subsonic and supersonic regimes on the line. Show by means of arrows the direction of heating and cooling processes on each branch of the line. State the values of Mach numbers at the points of maximum entropy and maximum temperature on the line.

Under what conditions the assumption of Raleigh flow is not valid in a heat exchanger?

(10)

(b) What are the advantages of generating steam at high pressure?

Explain with a neat sketch the constructional features and working of a Velox boiler.

(10)

(c) Helium gas (C_p = 5.19 kJ/kg-K, γ = 1.667) at 5 bar and 75 °C enters a convergent nozzle with negligible velocity and expands isentropic ally into a space at 3 bar. Calculate the mass flow rate per square meter of exit area.

(10)

(d) What is meant by effective temperature in comfort air-conditioning? Name the parameters that control it and discuss their individual role.

(10)

(e) The drag force F experienced by the object moving in a fluid of density ρ and viscosity μ depends upon its velocity V and diameter D. Using Buckingham's π theorem, obtain the relevant dimensionless groups.

(10)

6. (a) A steel pipe 120 mm diameter and 5 mm wall thickness, carrying steam at 300°C is insulated with 45 mm of glass wool followed by 50 mm of asbestos felt. The ambient temperature is 25°C. The heat transfer coefficients at the inside and outside surfaces are 650 and 20 W/m^2-K respectively. The thermal conductivities of steel, glass wool and asbestos felt are 55, 0.09 and 0.06 respectively. Calculate the rate of heat loss per unit length of pipe and the temperature of the outside surface.

(20)

(b) Sketch a typical load curve of a power plant and define the following terms:

Load factor; Capacity factor; Plant use factor. How do these factors influence the economics of power plant?

(15)

(c) Explain why aerofoil-shaped blades are used for axial compressors.

(5)

7. (a) Ethane (C_2H_6) is burned with dry air with 5 mol of oxygen for each mol of fuel. Calculate (i) per cent excess air, (ii) air-fuel ratio by mass, (iii) the wet and dry analysis of products by mass and (iv)dew-point temperature of products.

Assume air contains 21% 02 and 79% by volume and the atmospheric pressure is 100 kPa. Molecular weight of air is 29.

(15)

(b) The impeller of a centrifugal compressor is 70cm in diameter and delivers 7.5 kg/s of air while rotating at 15,000 r.p.m. Tip and root diameters of the eye annulus are 40 cm and 20 cm respectively. Inlet stagnation pressure and temperature are 1.01 bar and 300 K and the isentropic efficiency of compression 80%. Assuming power input factor of 1.05 and slip factor of 0.9 calculate the pressure ratio developed and the power required to drive the compressor. Determine the angle of the impeller vanes at the root and tip of the eye annulus, assuming that the axial velocity at inlet is constant at 150 m/s. Take C_p = 1.005 kJ/kg-K.

(25)

8. (a) With the help of H-s diagram, explain the term Reheat Factor in steam turbines. What are its effects on turbine performance? Why is it always more than 1?

(15)

(b) A two-stage steam turbine receives steam at 30 bar and 300 °C, and exhausts to a condenser at 0.05 bar. The pressure at the intermediate stage is 5 bar, Assuming an efficiency of 0.78 for each stage, calculate-

(i) quality of steam at the end of each stage;

(ii) Reheat factor;

(iii) Rankin efficiency.

(25)