# MECHANICAL ENGINEERING

## PAPER - I

## SECTION A

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

(a) A hollow shaft has greater strength in bending and higher stiffness in torsion than a solid shaft of equal weight and same material, Discuss.

(10)

(b) What are different types of drives? Give the advantages and disadvantages of belt drives.

(4 + 6)

(c) Explain what happens when austenite at a temperature above 723°C is cooled down by quenching.

(10)

(d) What are alloy steels? Discuss the effect of chromium and nickel as alloying element on the properties of steel.

(4 + 6)

(e) Give reasons for the popularity of Carbon Fibre Reinforced Plastics (CFRP).

(10)

2. (a) What is meant by critical speed in whirling of shaft? Show that if the speed of rotation of the shaft is very large compared to natural frequency of the shaft-disc system, the disc tends to rotate about its centre of gravity as the shaft deflects to accommodate the eccentricity (neglect viscous effect).

(3 + 10)

(b) Derive an expression for the acceleration of the piston of a reciprocating engine.

The following details pertain to a single cylinder vertical engine:

Bore = 20 cm, stroke = 40 cm, connecting rod length 80 cm, mass of reciprocating part = 140 kg, net gas pressure on the piston when the crank angle is 45° 65 N/cm$^2$ and speed of the engine = 300 rpm. Determine the turning moment on the crank shaft when the crank angle is 45°.

(7 + 8)

(c) The equation of motion of a spring- mass damper system with one degree of freedom executing forced vibration is given by

$$\frac{d^2y}{dt^2} + \frac{dy}{dt} + 49y = 10\sin\omega t.$$

where y is the displacement at any instant t and o is the angular velocity of the driving force. Determine:

(i) Natural frequency of un-damped free vibration

(ii) Critical damping co-efficient

(iii) Damping ratio

(iv) Static deflection

(v) Logarithmic decrement

(vi) Angular velocity of damped free vibration

(12)

3. (a) Calculate the change in volume of a cube of steel with sides measuring 15 cm when it is immersed to a depth of 800 m in sea water which weighs 10 kN/m$^3$. Take E = 200 GPa and Poisson's ratio v = 0.28

(10)

(b) At a point in a strained material, the resultant stress on a vertical plane is 100 MPa (tensile) making an angle of 30° (clockwise) with the normal to the plane. On the horizontal plane through the point, the resultant stress is compressive and makes 60° angle (clockwise) with the normal.

(i) Determine normal and shear stresses acting on the perpendicular planes.

(ii) Obtain principal stresses and principal planes.

(iii) Calculate maximum shear stress and normal stress on the planes of maximum shear stress.

(iv) On a properly oriented element, show principal planes and planes of maximum shear stress.

(5 + 10 + 10 + 5)

4. (a) What is the function of a follower in a cam follower pair? Sketch any four different types of follower.

(8)

(b) The torque exerted on the crank-shaft of a two-stroke engine is

$T = 12000 + 1800 \sin 2\theta - 1600 \cos 2\theta$ N-m

where θ is the crank angle measured from the inner dead centre position. If the resisting torque is constant, determine:

(i) Power developed by the engine when running at 150 rpm

(ii) Angular acceleration of the flywheel when crank has turned 30° if the mass moment of inertia of the flywheel is 212 kg-m$^2$.

(6+ 6)

(c) A simply supported beam of span [illegible] m carries a uniformly vaying load whose intensity varies from zero at the left support A to 12 kN/m run at right support B. Obtain shearing force and bending moment at sections 1.5 m and 4.5 m from the end A.

(20)

## SECTION B

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

(a) What is meant by forecasting? Explain basic exponential smoothing method for forecasting.

(2 + 8)

(b) What do you understand by the term Flexible Manufacturing System (FMS)? Draw the structure of a modern FMS.

(5 + 5)

(c) Explain the following:

(i) Degeneracy

(ii) Alternative Optima

(iii) Unbounded Solutions.

(4 + 3 + 3)

(d) Compare Computer Numerical Control (CNC) and Direct Numerical Control (DNC) systems.

(5 + 5)

(e) (i) State the importance of flow chart preparation while writing a computer software.

(ii) What is the use of mixed mode of operations in computer programming?

(5+ 5)

6. (a) What is meant by mach inability? Explain any four methods that give broad mach inability value?

(2 + 8)

(b) A machine tool is machining a steel block where the length of cut is 80 mm. The length of the chip is measured after annealing and straightening as $L_c$ = 63 mm. The tool is known to have a rake angle $\alpha$ = 40°. Other known conditions $V_c$ = 12 m/mim, depth of cut t = 0.02 mm, horizontal cutting force $F_c$ = 1250 N and vertical force $F_t$ = 430 N. Find the co-efficient of friction, chip ratio, thickness of chip, shear plane angle and velocity of the chip along the tool face.

(5)

(c) Explain a gas-assisted laser cutting method with a block diagram.

(10)

(d) Write the difference between inspection and manufacturing gages.

(5)

7. (a) What are the objectives of work-centre scheduling?

(5)

(b) Mr. Young is the Chief Controller of ABC Copy Express which provides copy services for customers. Five customers submitted their orders in the beginning of the week. Specific scheduling data are as follows:

| *Jobs in the order of arrival* | *Processing Time in Days* | *Due Date (Days Hence)* |
|---|---|---|
| P | 6 | 10 |
| Q | 8 | 12 |
| R | 4 | [illegible] |
| S | 12 | 18 |
| T | 2 | 4 |

All orders require the use of the only computerised colour copying machine. Mr. Young decides on the processing by using Shortest Operation Time rule. Find the total flow time and mean flow time.

(10)

(c) The following schedule for a liability work package done as part of an accounting audit in a corporation. Draw the CPM Network and find the CRITICAL PATH through TOTAL FLOAT calculation:

| Activity | Duration (Days) | Preceding Activities |
|---|---|---|
| A | 6 | None |
| B | 30 | A |
| C | 10 | A |
| D | 120 | A |
| E | 12 | D |
| F | 80 | B |
| G | 20 | C, E |
| H | 14 | F |
| I | 12 | G |
| J | 24 | H, I |

(5 + 15 + 5)

8. (a) In inventory control procedure, at what conditions, a plant manager will prefer to use a fixed-order quantity model as opposed to a fixed-time period model ? Explain.

(10)

(b) Explain the dimensions of DESIGN QUALITY with reference to TQM.

(10)

(c) XYZ Corporation produces 2 products. Unit profit for product A is Rs. 120!- and for product B is Rs. 100!-. Each must pass through 2 machines P and Q. Product A requires 20 minutes on machine P and 16 minutes on machine Q. Product B requires 40 minutes on machine P and 10 minutes on machine Q. Machine P is available 400 minutes a day, while Q is available 160 minutes a day. Due to operational set-up, the company must produce at least 2 units of product A and 5 of product B each clay. Units that are not completed in a given day are finished in the next day: that is portion of a product can be produced in the daily plan.

(i) Formulate the Linear Programming Problem.

(ii) Solve graphically showing all equations to find the most profitable production plan.

(iii) How should the resources be allocated?

# MECHANICAL ENGINEERING

## PAPER - I

## SECTION A

1. Answer any four parts:

(a) Show that the slope on the h—s diagram is equal to-

(i) T for a reversible constant pressure process;

(ii) $T-\left(\frac{1}{\beta}\right)$ for a reversible isothermal process;

(iii) $T+\frac{C_p-C_v}{\beta C_v}$ for a reversible constant volume process,

where β = coefficient of volume expansion. The following relations

$$C_p - C_v = Tv\beta^2 / K \text{ and } C_v = T\left(\frac{\partial S}{\partial T}\right)_v$$

can be used. K is compressibility.

(10)

(b) Given that

$$C_p = T\left(\frac{\partial S}{\partial T}\right)_p \text{ and } C_v = T\left(\frac{\partial S}{\partial T}\right)_v$$

Obtain the expressions of

$$\left(\frac{\partial C_p}{\partial p}\right)_T \text{ and } \left(\frac{\partial C_v}{\partial v}\right)_T$$

using Maxwell's and other relations.

Using the above derived equations, show that $C_p$ and $C_v$ for an ideal gas are functions of temperature only.

(10)

(c) Discuss the emissions from SI engines and CI engines. On what factors do these emissions depend and how can they be controlled?

(10)

(d) What do you understand by the term Availability?

6 kg of air at 600 K and 5 bars is enclosed in a closed system.

(i) Determine the availability of the system if the surrounding pressure and temperature are 1.0 bar and 300 K.

(ii) If the air is cooled at constant pressure to the atmospheric temperature, determine the availability and effectiveness.

(10)

(e) Define effectiveness for parallel and counter flow heat exchangers. Derive the expression of effectiveness for parallel flow heat exchanger.

(10)

2. (a) Explain the phenomenon of pre ignition. What are the dangers of pre-ignition? Why pre-ignition is more dangerous in multi-cylinder engines than in single-cylinder engine?

(15)

(b) What are the normal ranges of compression ratios for SI and CI engines? What limits the allowable compression ratio in these two engines?

(10)

(c) A 10cm dia x 12cm stroke, 4-cylinder, 4-stroke engine running at 2600 RPM has a carburettor venturi of 3.2 cm throat. Determine the suction pressure at the throat assuming the volumetric efficiency of the engine to be 70 per cent. Assume density of air to be 1.2 kg/m$^3$ and coefficient of airflow 0.82. Neglect compressibility air.

(15)

3. (a) Sketch Otto and Diesel cycles stating the various processes.

A diesel engine has a diameter of 20 cm and stroke of 30 cm. The clearance volume is 10 per cent of the swept volume. Estimate the compression ratio and the air-standard efficiency of the engine if the cut-off takes place at 10 per cent of the stroke.

(15)

(b) During the trial of a single-cylinder, 4-stroke oil engine, the following observations were made:

Cylinder diameter = 20 cm; stroke = 45 cm; mean effective pressure = 6 bars; torque = 500 N-m; speed = 260 RPM; oil consumption = 4.5 kglhr; calorific value of fuel 44000 kJ/ kg; cooling water flow rate = 5 kg/mim; air used/kg of fuel [illegible]0 kg; rise in cooling water temperature = 40°C; temperature of exhaust gases = 4[illegible]0°C; room temperature = 25°C; mean specific heat of exhaust gases = 1.0 kJ/ kg=K; specific heat of water = 4.18 kJ/kg-K.

Determine i.p., b.p., and draw a heat balance sheet for the test in kJ/hour.

(25)

4. (a) Air with an average velocity of 2 m/s and [illegible]0°C enters a copper tube of 11.2 mm inside diameter, 12 mm outside diameter and 1.0 m length. The tube wall is maintained at 100°C by condensing steam at atmospheric pressure. Neglect conduction thermal resistance of copper wall. The condensation heat transfer coefficient is 5000 W/m$^2$—K. Find the air side heat transfer coefficient and overall heat transfer coefficient. Then find outlet temperature of air using LMTD method. Properties of air at mean bulk temperature are

$k = 0.026$ W/m—K, $C_p = 1005$ J/kg—K,

$\rho = 1.17$ kg/m$^3$, $\nu = 1.6 \times 10^{-5}$ m$^2$/sec.

$$Nu = 3.66 + \frac{0.0668\ Re\ Pr \left(\frac{di}{L}\right)}{1 + 0.04\ Re\ Pr \left(\frac{di}{L}\right)} \qquad \text{if } Re < 2300$$

$$Nu = 0.023\ Re^{0.8}\ Pr^{0.4} \qquad \textbf{if } \mathbf{Re > 2300}$$

(20)

(b) (i) State Kirchhoff's law of radiation and show that for an opaque body ρ (1 - ε). Define irradiation and radiosity, and then show that net heat transfer from a gray body may be written as

$$Q = \frac{E_b - J}{(1 - \varepsilon) / \varepsilon A}.$$

(10)

(ii) A spherical Dewar flask of 300 mm and 400 mm inner and outside diameters, emissivities 0.05 for both surfaces is used for storing liquid oxygen at 50 K. The outer sphere is at 300K. Assuming radiation heat transfer only and assuming the flask to be full, find the evaporation rate of liquid $O_2$, given its latent heat = 214.2 kJ/ kg and $\sigma = 5.67 \times 10^{-8}$ W/m$^2$-K$^4$.

(10)

## SECTION B

5. Answer any four parts:

(a) Give the Clausius statement of the second law of thermodynamics and state Clausius inequality.

For the refrigeration system using first law and Clausius inequality, show that

$$COP \le \frac{T_E}{T_C - T_E}$$

(10)

(b) Show that

$$W = 0.622\left(\frac{p_w}{p - p_w}\right) \text{ and } \phi = \frac{W}{W_s}\frac{(0.622 + W_s)}{(0.622 + W)}$$

where $P_w$ and P are partial pressure of water vapour and total pressure respectively $W_s$ is humidity ratio at saturation and $\phi$ is relative humidity. Molecular weights of air and water vapour are 28.966 and 18.016 kg/kg-mole respectively.

(10)

(c) Explain clearly the following for compressible flow:

(i) Static and stagnation conditions

(ii) Critical velocity and maximum velocity attainable

Air airplane flies at an altitude, where the conditions are 216.5 K and 1.206 x 10 N/m$^2$ with a speed of 800 km/hr. Calculate:-

1. the maximum possible temperature on the airplane skin;
2. the maximum possible pressure intensity on the airplane body;
3. the critical velocity of the air relative to the airplane;
4. the maximum possible velocity of the air relative to the airplane.

(10)

(d) Explain Buckingham's π theorem and Rayleigh's method for dimensional analysis.

A circular cylinder of a given length/diameter ratio is kept in steady rotation at N revolutions/s in a uniform stream of fluid of velocity V. Assuming that the power required to maintain the motion depends on density ρ, kinematic viscosity ν of the fluid, the diameter D of the cylinder, and V and N, show that

$$P = \frac{\rho \nu^3}{D} f\left(\frac{VD}{\nu}, \frac{ND^2}{\nu}\right)$$

using Rayleigh's method only.

(10)

(e) With the help of a neat sketch, describe the working of a modern high pressure boiler.

6. (a) In a dense air refrigeration cycle, air enters the compressor at 3 bars and 10°C. It leaves the compressor at 15 bars. The compressed air is cooled to 27°C by external means. Assuming isentropic compression and expansion, find the temperatures after compression and expansion. For 1 TR cooling capacity, determine:—

(i) mass flow rate of air;

(ii) volume flow rates at turbine exit and compressor inlet;

(iii) compressor and turbine work;

(iv) COP.

Given γ = 1.4, R = 0.281 kJ/kg-K and C = 1.005 kJ/kg-K.

(20)

(b) In an air-conditioned space, 5 kg/s of fresh air at 45°C, 30 per cent relative humidity mixes with 45 kg/s of recalculated air at 25°C, 50 RH. The mixed air flows over a cooling coil whose apparatus dew point is 12°C and bypass factor is 0.15. Determine the conditions at the outlet of cooling coil RSH and RLH. The saturation pressures of water vapour at required temperatures are

| | |
|---|---|
| 12°C | 0.014016 bar |
| 25°C | 0.03166 bar |
| 45°C | 0.09584 bar |

Empirical equation for enthalpy of moist air is

$h = 1.005t + W(2500 + 1.88t)$ kJ/kg

$p = 1.01325$ bars

(20)

7. (a) In a closed cycle turbine, the working fluid at 50°C is compressed with [illegible] adiabatic effiency. It is then heated at constant pressure to 1100 K. The fluid then expands down to initial pressure in a turbine with an adiabatic efficiency of 0.85. After expansion it is cooled to 50°C. The pressure ratio is such that the work done per kg of fluid is maximum. The working fluid is assumed to be a perfect gas having $C_p$ = [illegible] kJ/kg-K and -y 1.4. Calculate the pressure ratio and cycle efficiency. Prove the formula for pressure ratio for maximum work done condition.

(25)

(b) The inter-cooling in a two-stage compressor is done upto temperature $T_a$ which is greater than inlet temperature $T_1$. Obtain the expression for optimum intermediate pressure such that total work is minimum. Assume polytrophic compression in both the stages.

(15)

8. (a) Explain clearly from economic point of view -

(i) load sharing between power plants;

(ii) load sharing between base load plant and peak load plant.

(15)

(b) Define the terms Load factor, Capacity factor and use factor.

A central power station has annual factors as follows:

Load factor = [illegible], capacity factor = 0.4, use factor 0.45.

The power station has a maximum demand of 15 MW. Determine-

(i) annual energy production;

(ii) reserve capacity over and above peak load;

(iii) hours per year the plant not in service.

(15)

(c) Give the advantages and disadvantages of Axial flow compressors over Centrifugal compressors.

(10)