MECHANICAL ENGINEERING Paper I

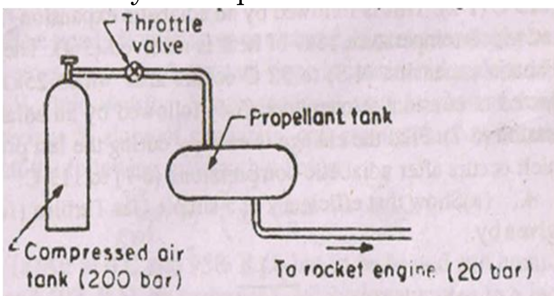
Time Allowed: Three Hours **Maximum Marks: 200**

INSTRUCTIONS

Please read each of the following instructions carefully before attempting questions.

Candidates should attempt **FIVE** *questions in all. Question No,* **1** *is compulsory.*
Out of the remaining **SIX** *questions attempt any* **FOUR** *questions.*
The number of marks carried by a part of a question are indicated against it.
Answers must be written in **ENGLISH** *only.*
Assume suitable data, if necessary, and indicate the same clearly.
For air R = 0.287 kJ/kg-K, C_p *= 1.005 kJ/kg-K, γ = 1.4, M = 28.97 kg/kg-mole, Universal gas constant R = 8.314 kJ/kg mole-K.*
Unless otherwise mentioned, symbols and notations have their usual standard meanings.
Neat sketches may be drawn, wherever required.
Attempts of questions shall be counted in chronological order. Unless struck off, attempt of a question shall be counted even if attempted partly.
Any page or portion of the page left blank in the answer book must be clearly struck off.
A psychrometric chart is attached to this question paper for necessary use by the candidate.

1. (a) Discuss flow energy. Compressed air is used to expel the liquid propellant from the propellant tank as shown below. The initial pressure of the air is 200 bar. The propellant has a density of 1.12 gm/cc and die propellant tank is filled to capacity and contains 900 kg of propellant. The propellant leaves at a constant pressure of 200 N/cm^2(20 bar). Considering the air as the system, determine the work done by the air in forcing the propellant from the propellant tank. Determine the volume of compressed air tank necessary to pump all the fuel in the rocket. Would the use of helium instead of air alter the performance? Is the inlet air temperature is of any consequence? 20



(b) The steam initially at a pressure of 15 bar and a temperature of 250 C, expand reversibly and polytropically to 1.5 bar. Find the final temperature, work done, and change of entropy, if the index of expansion is 1.25. (Assume 1 bar = 1 kgf/cm^2. State the assumptions made) 20

2. (a) A reversible engine receives heat from a mixture of water vapor and liquid water at 1 atm and rejects 3775 kJ/hr of heat at 100 K below temperature of a mixture of ice and liquid water at 1 atm. It delivers 0.386 kW power. Find the number of degrees separating absolute zero and ice point on Kelvin scale. 20

(b) A working fluid goes through a Carnot cycle of operations, the upper absolute temperature of the fluid being θ_1 and the lower absolute temperature being θ_2. The amount of heat taken in and rejected by the working fluid are Q_1 and Q_2 respectively. On account of losses of heat due to conduction etc., the heat source temperature T_1 is higher than θ_1 and the heat sink temperature T_2 is lower than θ_2. If $T_1 = (\theta_1 + K Q_1)$; $T_2 = (\theta_2 + K Q_2)$ where K is the same constant for both the equations, show that the efficiency of the plant is given by 20

$$\eta = 1 - \frac{T_2}{T_1 - 2KQ_2}$$

3. (a) Starting from first law equation dQ = du+ pdv show that change in entropy of an ideal gas system is given

$$\Delta S = C_V \ln\frac{T_2}{T_1} + R\ln\frac{V_2}{V_1}$$ 20

(b) A system operating in a reversible cycle receives 25 kJ of heat at 225°C (1-2). This is followed by an adiabatic expansion (2-3) to 115°C at which temperature 15 kJ of heat is received (3-4). Then a further adiabatic expansion (4-5) to 32°C occurs after which 25 kJ of heat is rejected at constant temperature (5-6) followed by an adiabatic compression (6-7). Find the change in entropy during the last process (7-1) which occurs after adiabatic compressions (6-7) to 115°C. 20

4. (a) Show that efficiency of a simple Gas Turbine (Joule cycle) is given by. 20

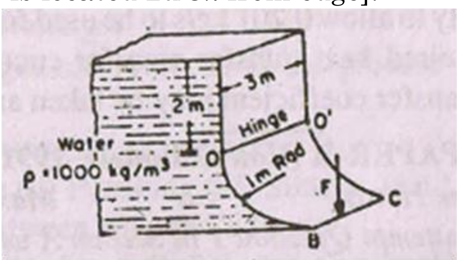
$$\eta = 1 - \left(\frac{1}{r}\right)^{\frac{\gamma-1}{\gamma}}$$

(b) The nozzles of a two-row velocity-compounded stage have outlet angles of 22 degrees and utilize an isentropic enthalpy drop of 200 kJ per kg of steam. All moving and guide blades are symmetrical, and the mean blade speed is 150 m/s. Assuming an isentropic efficiency for the nozzles of 90 percent, find graphically all the blade angles and calculate the specific power output produced by the stage. The velocity at inlet to the stage can be neglected. 20

5. (a) Define Volumetric Efficiency of a compressor. 5

(b) A multistage compressor has to be designed to supply air at 135 bar, while atmospheric condition is 1.03 bar and 15°C. The value of compression index may be assumed as 1.35. Due to practical reasons the intercoolers are not able to cool the air below 45°C, while the maximum temperature allowable in the system is 120°C.
Calculate the number of stages that are necessary in the compression and the rate of cooling water circulated per kg of air (C_p = 1 kJ/kg C). 35

6. (a) Calculate the force F required to hold the curved gate (projected area l1 × 1 m) of a reservoir as shown in figure below. [Data: $I_{XX} = bh^3/12$ for a rectangle and centroid for a quadrant is located 2d/3π from edge]. 20



(b) The steady flow in an open channel, exposed to atmosphere, of constant cross-section and constant slope is considered to depend upon velocity V, fluid density ρ, and cross-sectional area A, channel length *l*, wetted surface S, slope of channel s, and gravitational acceleration g. Show that the following relationship holds: 20

$$\frac{V^2}{g\sqrt{A}} = f\left(S, \frac{A}{S}, \frac{l}{\sqrt{S}}\right)$$

7. (a) Air at 0°C and 95% R.H. has to be heated and humidified to 25°C and 40% R.H. by preheating, adiabatic saturation in a recirculated water air-washer and then reheating to final state. Calculate heating required in two heaters, make-up water required in washer and temperature of air washer. 20

(b) A horizontal 3 mm-thick flat copper plate, 1 m long and 0.5 m wide, is exposed in air at 27°C to radiation from the sun. If the total rate of incident solar radiation is 300W and the combined unit-surface conductance on the upper and lower surfaces are 20 and 15 W/m^{2}K, respectively, determine the equilibrium temperature of the plate. 20

8. (a) The heat transfer coefficient for a gas flowing over a thin flat plate 3 m long and 0.3 m wide varies with distance from the leading edge according to h(x) = 10 $x^{-1/4}$ W/m^2 K. Calculate:

(a) the average heat transfer coefficient,

(b) the rate of heat transfer between the plate and the gas if the plate is at 170°C and the gas is at 30°C, and

(c) the local heat flux 2m from the leading edge. 20

(b) Light lubricating oil (C_p = 2090 J/kg K) is cooled by allowing it to exchange energy with water in a small heat exchanger. The oil enters and leaves the heat exchanger at 375 K and 350 K, respectively, and flows at a rate of 0.5 kg/s. Water (C_p = 4177 J/kg K) at 280 K is available in sufficient quantity to allow 0.201 kg/s to be used for cooling purposes. Determine the required heat transfer area for counterflow operation. The overall heat transfer coefficient may be taken as 250 W/m^{2}K. 20

MECHANICAL ENGINEERING Paper II

Time Allowed: Three Hours **Maximum Marks: 200**

INSTRUCTIONS

Please read each of the following instructions carefully before attempting questions:

Candidate should attempt **FIVE** *questions in all. Question No.* **1** *in Section* **A** *is compulsory.*

Out of the remaining, attempt **TWO** *from Section-***B** *and* **TWO** *from Section—***C**.

All questions carry equal marks. The number of marks carried by a part of a question is indicated against it.

Answer must be written in **ENGLISH** *only.*

Unless other-wise mentioned, symbols and notations have their usual standard meanings.

Neat sketches may be drawn, wherever required.

All parts and sub-parts of a question are to be attempted together in the answer book.

Attempts of questions shall be counted in chronological order. Unless struck off, attempt of a question shall be counted even if attempted partly.

Any page or portion of the page left blank in the answer book must be clearly struck off.

SECTION—A

1. Answer all 20 parts of the question each part carries 2 marks.

(a) What conditions should be satisfied, if a rigid link is to be replaced by a dynamically equivalent massless link with two point masses at its ends?

(b) Define logarithmic decrement. How is it related to damping ratio?

(c) What are primary and secondary unbalances in a slider-crank mechanism?

(d) State the condition for the stability of a governor. Why is an isochronous governor not stable?

(e) Define pressure angle and prime circle in reference to cam mechanism.

(f) Distinguish between modulus of elasticity and modulus of resilience of a material. In what situation is the latter property useful?

(g) Explain why maximum shear stress theory is widely used in machine design with ductile materials.

(h) Write Rankine-Gordon formula for buckling load of columns and explain the meaning of symbols used.

(i) Show by simple sketches die following welded joints:
(i) Single U-butt (ii) Single V-butt (iii) Single bevel butt (iv) Single J-butt.

(j) Differentiate between a closed coiled and an open coiled helical spring.

(k) Write down the compositions corresponding to the following specifications of steels:
(i) C 15 (ii) 55 Cr 7 (iii) 15 Mn 75 (iv) T 105 Cr 1 Mn 60

(l) Distinguish between white and nodular cast-iron.

(m) Distinguish between thermoplastics and thermosetting plastics.

(n) What is continuous casting process? List two primary areas in which this offers advantages.

(o) What four stages are involved in the process of resistance spot welding?

(p) What are following press operations?
(i) Blanking (ii) Punching (iii) Slitting (iv) Lancing.

(q) Differentiate between a jig and a fixture.

(r) Give an example for a facility location problem in which the objective may be to
(i) minimise total distance travelled,
(ii) minimise maximum distance travelled.

(s) What is material handling? Name four categories of material handling equipment used within plant.

(t) What is the purpose of production planning and operations scheduling?

SECTION—B

2. (a) A machine of mass 100 kg is mounted on isolators having stiffness of 1.2×10^6

N/m and a damping factor of 0.1. A piston of mass 2 kg within the machine has a reciprocating motion with a stroke of 8 cm and a speed of 1800 cycles/min. Assuming the motion of piston to be simple harmonic, determine

(i) the amplitude of motion of the machine,

(ii) force transmitted of the foundation,

(iii) the phase angles of the transmitted force and machine motion with respect to the exciting force. 20

(b) A steel cylinder having 12.5 cm outside diameter has a wall thickness of 1.5 cm. The cylinder is used as a pressure vessel to hold fluid at an internal pressure of 30 MPa. Assume that the ends of the cylinder are closed. Calculate

(i) the radial and tangential stress at the inner and outer surfaces,

(ii) the three principal normal strains at the inner surface, assuming that the material does not yield.

Take Young's modulus = 2×10^{11}N/m^2 Poisson's ratio = 0.3. 20

3. (a) An electric motor running at 500 rpm drives a low speed pump with a reduction of 1.8 : 1 through a pair of spur gears, which have teeth of 14½° involute form (module = 6 mm). The pinion has 20 teeth. In order that the interference does not take place, find

(i) the maximum working depth,

(ii) the lengths of path of contact arc of contact,

(iii) the maximum velocity of sliding on either side of pitch point. 20

(b) A vertical spring loaded valve is required for a compressed air receiver. The valve is to start opening at a pressure of 100 N/cm^2 gauge and must be fully open with a lift of 0.4 cm at a pressure of 120 N/cm^2 gauge. Diameter of port is 2.5 cm. Assume the following:

Allowable shear stress in spring steel = 480 N/mm^2

Modulus of rigidly for spring steel = 8×10^6 N/cm^2

Spring index (C) = 6

and calculate Ward's factor (K) by the following formula

$$K = \frac{4C-1}{4C-4} + \frac{0.616}{C}$$

Design a suitable close coiled round section helical spring having squared ground ends. Also specify initial compression and free length of the spring. 20

4. (a) Design a suitable ordinary rigid flange coupling to connect an electric motor to a reduction gear of a machine. The motor has a rated output of 80 hp at 600 rpm. Working stresses in materials to be used for different parts are

Flange (C.I.) : shear 1700 N/cm^2, compression 8400 N/cm^2;

Shaft (M.S.) : Shear 4750 N/cm^2

Bolt, Key (M.S): Shear 5800 N/cm^2, compressions 9000 N/cm^2.

These values take into account the service factor and weakening effect of the key way. Square keys are recommended for fixing the flanges on the shaft. For your calculations you may assume

Number of bolts = 4

Outside diameter of hub = 2d

P.c.d. of bolts = 3d

Width and depth of key = d/5

where d is the diameter of the shaft.

Make a fully dimensioned sketch of the coupling (one view only). 28

(b) A uniform cantilever beam with flexural rigidity EI is carrying a uniformly distributed load of magnitude w per unit length on its half length from mid span to free end. The length of cantilever is l. Derive an expression for bending deflection at the free end. You may use First Theorem of Castigliano. 12

SECTION—C

5. (a) Reason out why—

(i) A low carbon steel is not normally hardened by heat treatment,
(ii) Strength in austenitic steels is increased by work hardening,
(iii) A two-stage heating and cooling practice is usually followed for heat treatment in high speed steel. 10

(b) Compare the changes in various stages observed during tempering of a high carbon steel. 12

(c) Following data relate to a peripheral milling operation:
Dia of the milling cutter = 100 mm
Cutter speed = 500 rpm
Width of the cutter = 100 mm
Depth of the cut = 5 mm
Table speed = 100 mm/min
Helix angle of teeth = 45°
Length of workpiece = 50 cm
Width of workpiece = 80 mm
Number of teeth = 8
Calculate cutting speed, maximum effective uncut chip thickness, plane area of cut, metal removal rate and machining time. 18

6. (a) What is part programming? Explain the steps of preparing a part programme for feeding to a conventional NC machine. 12

(b) Describe the operation of a centreless grinder and state its advantage over the cylindrical grinder. 12

(c) The arrival rate of parts of a machinist is Poisson distributed with a mean of 8 per hour. A part can be machined in an average of 6 minutes, with a standard deviation of $\alpha = 8$ minutes. Consideration is being given to replacing this with an automated machine that can machine each part in exactly 6 minutes. What will be reduction in the average number of parts in queue? The reduction in time in queue? What would happen to be average number in the queue if, using the automated machinery, the Poisson arrival rate were increased to 10 per hour to match the constant service rate? 16

7. (a) Explain what is powder metallurgy and sintering. Discuss their major advantages over other processes. 10

(b) Discuss any four mechanisms for tool wear. 10

(c) A small plant layout job consists of 10 steps. Their precedence relationships and activity times are identified as follows:

Step	Predecessor	Time(Hours)
A	None	9
B	None	13
C	None	16
D	A	18
E	B	19
F	B	8
G	C, F	11
H	D, G	9
I	E, H	26
J	C, F	35

Draw the network and complete the forward and backward passes. What activities make up the critical path? Which activity has the most slack? 20