Civil Services (Main) Examination, 1999

MECHANICAL ENGINEERING

(Paper II)

Time Allowed : Three Hours	Maximum Marks : 300

QUESTION PAPER SPECIFIC INSTRUCTIONS

(Please read each of the following instructions carefully before attempting questions)

There are EIGHT questions divided in two Sections.
Candidate has to attempt FIVE questions in all.
Question Nos. 1 and 5 are compulsory and out of the remaining, any THREE are to be attempted choosing at least ONE question from each Section.
The number of marks carried by a question/part is indicated against it.
Wherever any assumptions are made for answering a question, they must be clearly indicated.
Word limit in questions, wherever specified, should be adhered to.

SECTION 'A'

1. Answer any three of the following (Answer to each part should not exceed 200 words)

(a)(i) Show that violation of the Kelvin-Planck statement of the Second Law of Thermodynamics implies the violation of Clausius statement. **10**

(a)(ii) Figure shows a system that undergoes a reversible cycle during which it exchanges heat with three thermal reservoirs and develops 1000 kJ of work per minute. Find the heat interchange Q_B and Q_C. **10**

[Figure: A cyclic device (circle) connected to three thermal reservoirs. Reservoir A at 1000 K (above) supplies 5000 kJ/min to the device (arrow from A down to the device). The device delivers work W = 1000 kJ/min (arrow to the right). The device is connected to reservoir B at 300 K (lower left), with the heat interaction marked Q_B / min, and to reservoir C at 500 K (lower right), with the heat interaction marked Q_C / min; the directions of Q_B and Q_C are not shown.]

(b) Explain the phenomenon of preignition in S.I. engines and how it can be detected. How does preignition lead to detonation and vice versa? What are the dangers of preignition? **20**

(c) What is Fanno flow? With the help of basic equations explain how Fanno line can be plotted on the h - s diagram. Give the effects of friction on various flow parameters and explain how choking occurs due to friction. **20**

(d) A power plant of 220 MW installed capacity has the following particulars: **20**

Capital cost	Rs. 40,000/kW installed
Interest and depreciation	15%
Annual load factor	70%
Annual capacity factor	64%
Annual running charges	Rs. 500×10^6
Energy consumed by power plant auxiliaries	6%

Calculate: (i) the cost of power generation per kWh. (ii) the reserve capacity

2. **(a)** Using Maxwell relation, derive Clapeyron equation. Hence derive Clapeyron-Clausius equation. **20**

(b) A single cylinder, two-stroke oil engine gave the following test data: Cylinder bore = 150 mm, stroke = 250 mm, engine speed 420 rev/min, the brake consists of a belt carrying a dead load of 48 kg on one end while the other end is attached to a spring balance reading 3 kg, the mean diameter of the friction brake = 1 m, area of indicator diagram = $2.8\,cm^2$, length of indicator diagram = 6.75 cm, the indicator spring rating is 0.92 mm/bar. Calculate the mechanical efficiency of the engine. **30**

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(c) Air is flowing steadily through a well lagged duct. Pressure and temperature of the air are measured at two stations A and B some distance apart along the duct. The readings obtained at these stations are **10**

	Station A	Station B
Pressure	1.3 bar	1.0 bar
Temperature	50 °C	13 °C

Deduce the direction of flow in the duct.

3. **(a)** The mass analysis of the petrol used in an engine was 85% C and 15% H_2. The dry exhaust gas analysis showed that the percentage by volume of carbon-dioxide was six times that of oxygen and that no carbon-monoxide was present. Calculate (i) the air-fuel ratio by mass. (ii) the percentage excess air supplied. Assume air contains 23.2% O_2 by mass or 20.9% O_2 by volume. **30**

(b) Discuss the various components of heating and cooling loads in air conditioning giving their classification. **15**

(c) What is cetane number of diesel fuel and how is it determined? What is the relationship between cetane number and octane number for petroleum derived fuels? **15**

4. **(a)** Explain, giving reasons, the requirements of air-fuel ratio in petrol engine using carburetor for the following range of operations (i) Starting (ii) Idling (iii) Maximum power (iv) Acceleration. State the additional systems provided in the simple carburettor to achieve the mixture strength for the above modes of operation. **30**

(b) What are the causes of smoke formation in a diesel engine? Describe the mechanism of smoke formation. What are the ways of controlling diesel smoke? **15**

(c) Steam exists in a power turbine with a dryness fraction of 0.85 and a pressure of 0.1 bar and is condensed to a saturated liquid. The lowest available temperature is 21 °C. What fraction of heat rejected to the condenser is available energy? **15**

SECTION 'B'

5. Answer any three of the following parts (Answer to each part should not exceed 200 words)

(a) What are the essential properties of a good refrigerant? What refrigerants are used and what factors are considered in selecting a refrigerant for (i) Ice production factory and (ii) Domestic refrigerators? What are the recent trends in refrigerants to avoid ozone depletion in the stratosphere? **20**

(b) Using dimensional analysis, derive an expression for the Nusselt number in terms of Prandtl and Grashof numbers for free convection heat transfer system. **20**

(c) Hot air at a temperature of 80 °C is flowing through a steel pipe of 10 cm diameter, The pipe is covered with two layers of different insulating materials of thickness 6 cm and 3 cm, their corresponding thermal conductivities are 0.23 and 0.37 W/m K respectively. The inside and outside heat transfer coefficients are 60 and $10\,W/m^2K$. The atmospheric temperature is 27 °C. Find the rate of heat loss from a 60 m length of pipe. Neglect resistance of steel pipe. **20**

(d) Discuss with a diagram the design and off-design performance of a convergent-divergent nozzle explaining clearly the terms ‘over expanding’ and ‘under expanding’ **20**

6. **(a)** Give a schematic diagram of a modern large capacity high pressure boiler and discuss its special features. What is the advantage of providing both convective and radiative superheaters in the boiler plant? **20**

(b) A counter flow heat exchanger of heat transfer area of $16.7\,m^2$ is to cool oil ($C_{ph}=2000$ J/kg s) with water ($C_{pc}=4170$ J/kg s). The oil enters at $t_{h,in}=100\square^{\circ}C$ and $m_h=2.0$ kg/sec while the

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water enters at $t_{c,in}=20\square^{\circ}C$ and $m_c=0.42$ kg/s. The overall heat transfer coefficient is $U=300\,W/m^2\square^{\circ}C$. Calculate the exit temperature of water $t_{c,out}$ and the total heat transfer rate Q. **40**

7. **(a)(i)** Discuss the considerations for the selection of sites for thermal, nuclear and hydel power plants. **10**

(a)(ii) What do you understand by base load plant and peak load plant and what are the criteria for their selection? **10**

(b) An ammonia vapour compression refrigeration plant has two stages of compression and one evaporator. After leaving the condenser at 11.666 bar as saturated liquid without under-cooling it passes the first throttle valve from which it emerges at 4.975 bar to enter a flash chamber. The liquid from flash chamber is then throttled to 2.909 bar and passes to the evaporator while the dry saturated vapour is passed to a receiver connecting the L.P and H.P cylinders. Determine (i) the amount of vapour bled off at the flash chamber. (ii) the coefficient of performance. Properties of ammonia: **40**

Pressure bar	Temperature °C	Enthalpy kJ/kg: h_f	Enthalpy kJ/kg: h_g	Entropy kJ/kg K: s_f	Entropy kJ/kg K: s_g	C_p kJ/kg K
11.665	30	332.9	1467.9	1.2028	4.9805	2.958
4.975	4	199.6	1447.6	0.7815	5.2852	2.958
2.909	– 10	135.2	1432.0	0.5440	5.4730	2.958

8. **(a)** A centrifugal compressor running at 18000 rev/min takes in air at 25 °C and compresses it through a pressure ratio of 4.0 with an isentropic efficiency of 80%. Guide vanes at inlet give the air an angle of pre-whirl of 20° to the axial direction. The mean diameter of impeller eye is 225 mm. The absolute air velocity at inlet is 130 m/s. At exit the blades are radially inclined. If the slip factor is 0.90, calculate the impeller tip diameter. **30**

(b) At a particular stage of a reaction turbine the mean blade speed is 140 m/s and the steam is at a pressure of 20 bar with a temperature of 250° C. Fixed and moving blades at this stage have inlet angles 30° and exit angles 20°. The stage efficiency is 80%. Determine (i) the specific enthalpy drop across the stage in kJ/kg. (ii) the drum diameter and blade height of the blade height is one-twelfth of the drum diameter and the steam flow is 120 kg/s. (iii) the percentage increase in relative velocity across the bladings as a result of the pressure drop across the blading. **30**

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