Civil Services (Main) Examination, 2001

# 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 parts (Answer to each part should not exceed 200 words) **20×3=60**

**(a)** The ratio of heat transfer to work transfer in the process of an air compressor reciprocating type is 1/4, If the compression follows $p v^n$ = constant, what is the value of n? Derive the equation that you use. In such a compression process the work required is 200 kJ/kg and the specific heat at constant volume is 0.75 kJ/kg K. What rise of temperature is expected at the end of compression process?

**(b)** What is the available energy i.e., the maximum amount of work that can be obtained from 1 kg of air at state point 1 in the figure? The dead state is also marked '0' in the figure?

[Figure (printed above the text): T–s diagram (T vertical, S horizontal). Two constant-pressure lines rising to the right: the upper one marked $P_1 = 10$ atm and the lower one marked $P_0 = 1$ atm. State point 1 lies on the $P_1$ line at T = 600 K; state point 0 (dead state) lies on the $P_0$ line at T = 300 K. Horizontal lines drawn at 600 K and 300 K.]

**(c)** What are the fan laws? Discuss at least three methods which are used to control fan output (Q) in a power plant.

**(d)** Show that in a 50% reaction turbine stage, the maximum stage efficiency is given by, $\frac{2\cos^2\alpha}{1+\cos^2\alpha}$

where, α is the nozzle angle.

**2.** **(a)** A power generating station has a maximum demand of 20 MW. The daily load on the station is as follows: (i) Draw the load curve and load duration curve for the plant. (ii) Decide the capacity and number of units, (iii) Prepare the operating schedule of the units. (iv) Determine the load factor, plant capacity factor and plant use factor of the station. **30**

| Time | Load, MW |
|---|---|
| 6 AM to 8 AM | 7 |
| 8 AM to 12 NOON | 16 |
| 12 NOON to 1 PM | 6 |
| 1 PM to 5 PM | 15 |
| 5 PM to 7 PM | 17 |
| 7 PM to 9 PM | 20 |
| 9 PM to 11 PM | 9 |
| 11 PM to 6 AM | 4 |

*English version compiled from published transcriptions and cross-checked across sources; not a facsimile of the official UPSC question paper.*



Optional Province · optionalprovince.com

**(b)** Develop the Clapeyron equation for the pure substance changing the phase. Hence find the enthalpy of evaporation for R-22 at -10°C and compare the same with the tabulated value. What is the percentage error involved? **30**

Properties of R-22

| $T_s$, °C | $p_s$, kPa | $v_f$, litres/kg | $v_g$, $m^3/kg$ | $h_{fg}$, kJ/kg |
|---|---|---|---|---|
| -20 | 244.72 | 0.7409 | 0.0929 | 220.331 |
| -10 | 354.16 | 0.7587 | 0.0654 | 213.136 |
| 0 | 497.41 | 0.7783 | 0.0472 | 205.369 |

**3.** **(a)** A four cylinder engine of a truck has been converted to run on propane fuel. A dry analysis of the engine exhaust gives the following volumetric percentages $CO_2$ - 4.90 CO - 9.79 and $O_2$ - 2.45. Calculate the equivalence ratio at which the engine is operating. **30**

**(b)** Explain the following (i) Rich mixture is used during idling. (ii) As the engine speed increases, the ignition timing should be advanced. (iii) S.I. engines are generally not supercharged. (iv) Two stroke C.I. engines find wide applications in marine propulsion. **30**

**4.** **(a)** A three liter V 6 S.I. engine operates on a four stroke cycle at 3600 rpm. The compression ratio is 9.5, the length of the connecting rod is 16.6 cm and the engine is square (bore = stroke). At this speed, the combustion ends at 20° ATDC. Calculate (i) cylinder bore and stroke length (ii) average piston speed (iii) clearance volume of one cylinder (iv) piston speed at the end of combustion (v) distance the piston has travelled from TDC at the end of combustion. (vi) volume in the combustion chamber at the end of combustion. **30**

**(b)** Derive an expression for the air-fuel ratio delivered by a simple carburettor. Discuss its limitations. What are the systems incorporated to overcome the limitations of a simple carburettor?

## SECTION 'B'

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

**(a)** Show that volumetric clearance efficiency of a reciprocating compressor is given by: $\eta_{vw}=1+cl-\{cl(p_d/p_s)^{1/n}\}$ [?] where cl is clearance ratio and suffix d & s refer to discharge and suction pressures. **20**

**(b)** Discuss and show on the skeleton psychrometric chart, the process for the air passing through air washers with three types of spray (i) recirculated (ii) chilled and (iii) heated water. **20**

**(c)** How, in a refrigeration system using ammonia, the compressor could be replaced by another suitable set of equipments? **20**

**(d)** Show that: $Nu(Pr)^{-1/3}=\{St(Pr)^{2/3}\}Re$. **20**

**6.** **(a)** Calculate the (i) cop. (ii) power requirement and (iii) cooling capacity of a $CO_2$ compressor working between 22.68 bar and 64.32 bar pressures. The liquid in the condenser gets cooled, by another system, to 15°C before entering the expansion valve. The system is assumed to work on wet-compression with x = 0.9. The compressor data stroke volume = 500 c.c.; r.p.m. = 500 and $\eta_{vol}=0.85$. Property values are: sp. heat of $CO_2$ vapour = 2.4 kJ/kg°C and **30**

| p (bar) | enthalpy (kJ/kg) liq. | enthalpy (kJ/kg) vap. | v ($m^3/kg$) liq. | v ($m^3/kg$) vap. | S (kJ/kg°C) liq. | S (kJ/kg°C) vap. | t (°C) |
|---|---|---|---|---|---|---|---|
| 22.68 | 49.62 | 322.86 | 0.00101 | 0.0166 | 0.1976 | 1.2567 | -15 |
| 50.92 | 127.75 | 308.08 | 0.00130 | 0.0066 | 0.4697 | 1.0959 | 15 |
| 64.32 | 164.17 | 283.63 | 0.00147 | 0.0042 | 0.5903 | 0.9912 | 25 |

**(b)** In an air-conditioning plant equipment exists for reheating the air before supply to a room to be maintained at 25° dbt with 55% R.H. The RSHL = 150,000 W and RLHL = 122,000 W. The



Optional Province · optionalprovince.com

discharge from cooling coil is 12°C dbt, 95% R.H. Calculate: (i) the supply air state and rate (ii) reheating, if any. **30**

**7.** **(a)** A 3 m long 25 mm dia tube is held at 100°C by steam jacketing. Water flows through the tube @ 180 kg/hr at 20°C. Calculate the rate of heat transfer from the tube to water. For water (60°C): $C_p = 4.178\, kJ/kg\,K$; $k = 0.66\,(W/m\,K)$; $\rho = 983\, kg/m^3$ and $\mu = 0.47 \times 10^{-3}\, kg/m\,s$. **30**

**(b)** The surface of two circular discs parallel to each other, each with 1 $m^2$ area, are exchanging thermal radiation with each other and with the surrounding walls. The temperatures of disc 1, disc 2 and the walls are 800K, 500 K and 300 K respectively. The shape factor between discs is 0.5. Compute with help of network analysis the net radiative heat transfer between the two discs. **30**

**8.** **(a)** The velocity of steam entering a simple impulse turbine is 1000 m/s and the nozzle angle is 20°. The mean peripheral velocity of blades is 400 m/s. The blades are asymmetrical. If the steam is to enter the blades without shock, that will be the blade angles? Neglecting the friction effects on the blades, calculate the tangential force on the blades and the diagram power for a mass flow of 0.75 kg/s. Calculate the axial thrust and diagram efficiency. **30**

**(b)** Clearly explain as to how the circulation is maintained in modern boilers having operating pressures 100 bar, 180 bar and 240 bar respectively? What is circulation ratio? What is the normal range of circulation ratio in case of utility boilers and industrial boilers? **30**

✶ ✶ ✶



Optional Province · optionalprovince.com