Range Forest Officer (Main / Written) Examination, 2021

MECHANICAL ENGINEERING

Time Allowed: Three Hours | Maximum Marks: 200

Question Paper Specific Instructions

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

1. There are 08 (eight) questions in all, out of which FIVE are to be attempted.
2. Question Nos.1 and 5 are compulsory. Out of the remaining SIX questions, THREE are to be attempted selecting at least ONE question from each of the two Sections I and II.
3. Answers must be written in legible handwriting. Each part of the question must be answered in sequence and in the same continuation.
4. All questions carry equal marks. The number of marks carried by a question / part is indicated against it.
5. Attempts of questions shall be counted in sequential 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 Booklet must be clearly struck off.
6. Unless otherwise mentioned, symbols and notations have their usual standard meanings. Assume suitable data, if necessary and indicate the same clearly.
7. Neat sketches may be drawn, wherever required.
8. Use of IS:456 and IS:800 is permitted.
9. Use of structural steel tables is allowed.
10. Re-evaluation / Re-checking of answer book is not allowed.

SECTION-I

1. (a) (i) A train reservation facility has 5 counters, each capable of handling 20 requests per hour. The persons coming for reservation arrive at a mean rate of 90 per hour. Assume that each person comes with one request only and the time to serve a request is constant. Calculate: (10)

   (i) Mean number of persons at any time at this facility

   (ii) The mean time a person spends at the facility

   (iii) The average length of queue at each counter

   (ii) Write any four objectives of value engineering. What are the elements of value engineering? (10)

   (b) Two 20º involute spur gears mesh externally and give a velocity ratio of 3. The module is 3 mm and the addendum is equal to 1.1 module. If the pinion rotates at 120 rpm, determine the:

(20)

(i) Minimum number of teeth on each wheel to avoid interference

(ii) Contact ratio

2. (a) (i) Name the three costs involved in inventory control. A store procures and sells certain items. Information about an item is as follows: (10)

Expected annual sales = 8000 units

Ordering cost = Rs 1800 per order

Holding cost = 10% of average inventory value

The items can be purchased according to the following schedule:

Lot Size	Unit Price (₹)
1-999	220
1000-1499	200
1500-1999	190
2000 and above	185

Determine the best order size? (10)

(ii) Explain the importance of surface finish and define the following terminologies: (10)

(i) Effective surface

(ii) Primary texture

(iii) Secondary texture

(iv) Lay

(b) Explain the principle of ECM. List the requirements of tool materials and applications of ECM. What are its advantages? (20)

3. (a) (i) Explain the principle of explosive forming. Compare confined and non-confined systems of explosive forming. (10)

(ii) A suspension cable, with supports at the same level, has a span of 30 m and maximum dip of 3 m. The cable is loaded with a uniformly distributed load of 10 kN/m throughout its length. Find from first principles, the maximum tension in the cable. (10)

(b) A shaft is to be designed for transmitting 100 kW power at 150 rpm. The shaft is supported in bearings 3 m apart. A pulley mounted at 1 m from one bearing exerts a transverse load of 30 kN. Determine the diameter of shaft if the maximum direct stress is not to exceed 100 N/mm^2. (20)

4. (a) (i) The stress state at a point in a body plane with $\sigma_1 = 60$ N/mm^2 and $\sigma_2 = -36$ N/mm^2. If the allowable stress for the material in simple tension or compression is 100 N/mm^2, calculate the values of factor of safety with each of the following criteria for failure: (10)

(i) Maximum stress criteria

(ii) Maximum distortion energy criteria

(ii) Enumerate the inversion of double slider crank chain giving examples. (10)

(b) A beam of length 5 m and of uniform rectangular section is simply supported at its ends. It carries a uniformly distributed load of 9 kN/m running over the entire length. Calculate the width and depth of the beam if permissible bending stress is 7 N/mm^2 and central deflection is not to exceed 1 cm.

Take E for beam material = 1×10^4 N/mm^2 (20)

SECTION-II

5. (a) (i) Discuss the reasons involved in varying mixture requirements for idling, cruising and power range at various throttle? (10)

(ii) Show that the discharge over a spillway is given by

$$Q = VD^2 f\left(\frac{\sqrt{gD}}{V}, \frac{H}{D}\right)$$

where V=velocity of flow, D=depth at the throat, H=head of water, and g=acceleration due to gravity. (10)

(b) In an air standard diesel cycle, the compression ratio is 15. Compression begins at 0.1 MPa, 40ºC. The heat added is 1.675 MJ/kg. Find (a) the maximum temperature of the cycle (b) the work done per kg of air (c) the cycle efficiency (d) the temperature at the end of the isentropic expansion (e) the cut-off ratio (f) the maximum pressure of the cycle, and (g) mean effective pressure of the cycle? (20)

6. (a) (i) What are the main components of a flat plate solar collector? Explain function of each component. (10)

(ii) Two identical circular plates each with area 1 m^2 and emissivity 0.5 are arranged facing each other in a large room. The emissive power of the plates are 30 kW/m^2 and 3 kW/m^2 respectively. The temperature of the surrounding is 27 ºC. The surface of the plates facing each other only are radiating energy, find: (10)

(i) Distance between the plates

(ii) Temperature of the plates

Assume the shape factor between the plates as 0.6

(b) Considering isentropic flow in a nozzle. Show that

$$\frac{p^*}{p_0} = \left\{\frac{2}{\gamma+1}\right\}^{\frac{\gamma}{\gamma-1}}$$

$$\frac{\rho^*}{\rho_0} = \left\{\frac{2}{\gamma+1}\right\}^{\frac{1}{\gamma-1}}$$

$$\frac{T^*}{T_0} = \frac{2}{\gamma+1}$$

where, * refers to M=1 and subscript zero refers to stagnation condition. (20)

7. (a) (i) A mild steel tank of wall thickness 12 mm contains water at 95 ºC. The thermal conductivity of mild steel is 50 W/m ºC, and the heat transfer coefficients for the inside and outside the tank are 2850 W/m^2 ºC and 10 W/m^2 ºC, respectively. If the atmospheric temperature is 15 ºC, calculate: (10)

(i) The rate of heat loss per m^2 of the tank surface area

(ii) The temperature of the outside surface of the tank.

(ii) State and prove Carnot theorem. (10)

(b) A F-12 vapour compression refrigeration system has a condensing temperature of 50 ºC and evaporating temperature of 0 ºC. The refrigeration capacity is 7 tonnes. The liquid leaving the condenser is saturated liquid and compression is isentropic. Determine: (20)

(i) The refrigeration flow rate

(ii) The power required to run the compressor

(iii) The heat rejected in the plant

(iv) COP of the system

The properties of F-12 are:

Temperature (ºC)	Pressure (bar)	h_f (kJ/kg)	h_g (kJ/kg)	s_f (kJ/kg K)	s_g (kJ/kg K)
50	12.199	84.868	206.298	0.3034	0.6792
0	3.086	36.022	187.397	0.1418	0.6960

Take enthalpy at the end of isentropic compression = 210 kJ/kg.

8. (a) (i) A copper pipe carrying refrigerant at -20ºC is 10 mm in OD and is exposed to convection at 50 W/m^2K to air at 25ºC. It is proposed to apply insulation of conductivity 0.5 W/mK. Determine the thickness beyond which the heat gain will be reduced. Calculate the heat gains for 2.5 mm, 5.0 mm, and 7.5 mm thicknesses for 1 m length. The convection coefficient remains constant. (10)

(ii) An ideal gas is heated at constant volume until its temperature is three times the original temperature, then it is expanded isothermally till it reaches its original pressure. The gas is then cooled at constant pressure till it is restored to the original state. Determine the net work done per kg of gas if the initial temperature is 350K? (10)

(b) What is the difference between mountings and accessories of a boiler? Explain various mountings and accessories along with suitable diagrams. (20)

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