A-GTD-O-NDAA

MECHANICAL ENGINEERING

Paper I

(Conventional)

Time Allowed : Three Hours *Maximum Marks : 200*

INSTRUCTIONS

Please read each of the following instructions carefully before attempting the 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 is indicated against it.

Answers must be written in ENGLISH only.

Assume suitable data, if necessary, and indicate the same clearly.

For air $R = 0{\cdot}287$ kJ/kg-K, $C_p = 1{\cdot}005$ kJ/kg-K,

$\gamma = 1{\cdot}4$, $M = 28{\cdot}97$ kg/kg-mole, Universal gas constant

$R = 8{\cdot}314$ 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.

1. (a) An inventor claims to have designed an equipment which takes in air at 0·5 MPa and 27°C and gives two streams of equal mass of air, one hot stream at 0·1 MPa and 400 K and the other cold stream at 0·1 MPa and 200 K. It is also claimed that the equipment does not require energy either in the form of heat or work. Judge whether it is theoretically feasible or not based on the thermodynamic principles. *10*

(b) A steel pipe of diameter 8·9 cm has eight longitudinal fins of 1·5 mm thickness which extend, 30 mm from the pipe surface. If the thermal conductivity of the fin material is 45 W/mK, find the percentage increase in the rate of heat transfer for the finned surface compared to the base surface. Assume the film heat transfer coefficient as 75 W/m^2K. *10*

(c) (i) What is boundary layer separation ? Explain with neat sketches, the sufficient and necessary conditions for boundary layer separation. What are the common methods to control boundary layer separation ? *7*

(ii) For the velocity profile,

$$\frac{u}{U_\infty} = \left(\frac{y}{\delta}\right)^{1/7},$$

calculate the momentum boundary layer thickness in terms of the nominal thickness 'δ' of the boundary layer. *3*

(d) (i) Define RSHF, GSHF and ESHF. Show them on a skeleton psychrometric chart. 5

(ii) Air at a temperature of 30°C flows over a flat plate of length 2 m, which is maintained at 150°C. The air flows with a velocity of 12 m/s. Find the local heat transfer coefficient at a distance of 0·5 m from the leading edge, and at the trailing edge. What is the type of flow at these two sections ? At what length, does the flow pattern change ?

The properties of air at the mean temperature of 90°C are

$C_p = 1{\cdot}01$ kJ/kg °C, $\rho = 0{\cdot}962$ kg/m^3,

$\mu = 2{\cdot}131 \times 10^{-5}$ kg/m-s, $k = 0{\cdot}031$ W/mK.

Use the equations :

$Nu = 0{\cdot}332\ Re^{0{\cdot}5}\ Pr^{0{\cdot}33}$ for laminar flow and

$Nu = 0{\cdot}0296\ Re^{0{\cdot}8}\ Pr^{0{\cdot}33}$ for turbulent flow. 5

(e) (i) Draw the velocity triangles at the outlet and theoretical "head vs discharge" curves for a centrifugal pump with forward curved, radial and backward curved vane impellers. 5

(ii) A centrifugal pump delivers water against a head of 16 m. The external and internal diameters of the impeller are 400 mm and 200 mm respectively. Find the minimum starting speed of the pump. 5

(f) In case of turbocompressors such as centrifugal and axial flow compressors, isentropic efficiency, and in the case of reciprocating compressors, isothermal efficiency are used as the reference. Explain why. Derive an expression for the volumetric efficiency of a single stage reciprocating compressor. Explain with the help of P-V diagram, the effect of pressure ratio and clearance volume on volumetric efficiency. *10*

(g) A certain mass of air is initially at 260°C and 700 kPa and occupies 0·028 m^3. The air is expanded at constant pressure to 0·084 m^3 A polytropic process with n = 1·50 is then carried out, followed by a constant temperature process which completes the cycle. All the processes are reversible processes.

(i) Sketch the cycle on P-v and T-s coordinates and (ii) find the efficiency of the cycle. *10*

(h) (i) Define DBT, WBT, DPT, Relative humidity (R.H.) and Specific humidity with respect to the properties of moist air. *4*

(ii) Show a schematic sketch of a winter air-conditioning system and explain all the processes involved. *6*

2. (a) A 1 : 20 scale model of a submarine is tested in a wind tunnel to measure the drag on the proposed design. A prototype speed of 18 kmph is desired. What speed should be used in the wind tunnel for the model testing ? Estimate the ratio of drag forces between the model and the prototype. Use the following property values : *10*

Fluid	Density kg/m^3	Viscosity $N\text{-}s/m^2$
Air	1·22	1×10^{-5}
Sea water	1025	$1{\cdot}5 \times 10^{-3}$

(b) A copper wire of 5·2 mm diameter is insulated with a layer of PVC of thermal conductivity 0·43 W/mK. The wire carries current and its temperature is 60°C. Film coefficient on the air side is 11·35 W/m^2K. Calculate the critical thickness of insulation. Also calculate the heat loss from the wire with the critical thickness of insulation. Find the heat transfer for insulation thickness of 20 mm and 60 mm. Ambient air temperature is 30°C. *10*

(c) In SI engines knocking occurs near the end of combustion whereas in the CI engines knocking occurs near the beginning of combustion. Explain the factors responsible for knocking in SI engines. *10*

3. (a) A 3-jet pelton turbine is required to generate 10,000 kW under a net head of 400 m. The blade angle at outlet is 15° and the reduction in the relative velocity while passing over the blades is 5%. If the overall efficiency of the wheel is 80%, $C_v = 0{\cdot}98$ and speed ratio = 0·46. find (i) the diameter of the jet, (ii) the flow rate and (iii) the force exerted by a jet on the buckets. 10

(b) (i) The lubricating oil used in a gear box of a compressor is being recirculated through a double pipe heat exchanger for cooling. The oil is to be cooled from 70°C to 40°C using water available at 28°C. Flow rate of the oil is 1000 kg/hr. Water exit temperature should not exceed 42°C. C_p of oil is 2·05 kJ/kg-K, C_p of water is 4·17 kJ/kg-K. Calculate the required water flow rate and the area of the heat exchanger. Assume counter flow. Also assume the overall heat transfer coefficient to be 300 W/m^2K. 5

(ii) A refrigerator is placed near a partition wall of a room such that there is only a 4 cm gap between the wall and the refrigerator surface facing the wall. The refrigerator surface is of 1·6 m height and 0·8 m breadth and has a temperature of 22°C. The wall temperature is 30°C. Calculate the rate of heat gain by the refrigerator surface.

Assume the properties of air at 26°C :

$\nu = 1{\cdot}684 \times 10^{-5}$ m^2/s, k = 0·26 W/mK,

$\alpha = 2{\cdot}21 \times 10^{-5}$ m^2/s, Pr = 0·7.

Use the equation,

$$Nu = 0{\cdot}42 \,.\, Ra_w^{0{\cdot}25} \,.\, Pr^{0{\cdot}012} \,.\, \left(\frac{L}{W}\right)^{-0{\cdot}3}$$

(where Ra is the Rayleigh number). 5

(c) Prove that for Van der Waals gas, C_v is a function of temperature only. Van der Waals equation is given by $P = \left(\frac{RT}{(v-b)} - \frac{a}{v^2}\right)$ 10

4. (a) A simple R-12, heat pump, used for space heating, operates between 15°C and 50°C. Heat required to be pumped is 100 mJ/hr. Calculate the quality of the refrigerant entering the evaporator, mass flow rate of the refrigerant and discharge temperature coming out of the compressor, theoretical piston displacement, power required for the compressor and the COP.

Assume C_p of vapour as 0·8 kJ/kg-K and specific volume of saturated vapour at 15°C as 0·0354 m^3/kg. 10

Properties of R-12

t_{sat} °C	P_{sat} kPa	h_f kJ/kg	h_g kJ/kg	s_f kJ/kg-K	s_g kJ/kg-K
15	0·491	50·1	193·8	0·1915	0·6902
50	1·291	84·9	206·5	0·3037	0·6797

(b) In a gas turbine plant, air at 10°C and 1·0 bar is compressed to 12 bar with isentropic efficiency of 80%. The air is heated first in the regenerator and then in the combustion chamber till its temperature is raised to 1400°C, and during this process the pressure falls by 0·2 bar. The air is then expanded in the turbine, and then passes through the regenerator, which has an effectiveness of 0·75 and causes a pressure drop of 0·2 bar. Isentropic efficiency of the turbine is 85%. Determine the thermal efficiency of the plant. Assume addition of heat at constant pressure. *19*

(c) Steel balls used in ball bearings are quenched by suddenly dropping the hot balls in a cold oil bath. Steel balls of 50 kg mass initially at 200°C and with specific heat 0·45 kJ/kg-K are quenched in an oil bath of initial temperature 30°C and specific heat 2·8 kJ/kg-K. During the quenching, a paddle-wheel driven by a 200 W motor is activated to stir the oil. Thermal equilibrium is established after 20 minutes, when the final temperature is 40°C. Determine the mass of the oil and the entropy generated during the process. Consider the tank containing the oil to be well insulated and of negligible mass. *10*

5. (a) (i) Find the shape factors of the two surfaces, one is the hemispherical surface of same diameter and the second a flat surface of the same diameter, comprising an enclosure. *2*

(ii) A steel ball of 0·3 m diameter and at 800 K is cooled by radiation only, to the ambient at 30°C. Find the time required for the ball to cool to 70°C. Assume the density and specific heat of steel as 780 kg/m^3 and 0·473 kJ/kg-K respectively. Assume the surface of the steel ball to be black. *8*

(b) (i) Draw an indicator diagram showing the effect of acceleration and friction in a single stage reciprocating pump. Explain the various heads and the considerations to decide the safe speed of the pump. *5*

(ii) What is an air vessel ? Give the chief advantages of fitting air vessels on the suction and delivery sides of a reciprocating pump. *5*

(c) In a BWR type nuclear reactor, the heat of nuclear fission is transferred to water In a reactor, water comes out of the reactor as saturated vapour at 72 bar. The steam flows through a turbine and exhausts at 0·08 bar to a condenser. The water leaves the condenser at 0·08 bar and 40°C (h = 176·5 kJ/kg). The liquid water is again pumped through a pump to the nuclear reactor. Isentropic efficiency of the turbine is 70%. The plant has a capacity of 750 MW. Calculate the mass flow rate of steam circulated and the rate of heat generation.

Properties of steam :

P = 0·08 bar : h_f = 173·9 kJ/kg, h_{fg} = 2403·2 kJ/kg,

s_f = 0·5926 kJ/kg-K, s_{fg} = 7·5370 kJ/kg-K,

At 72 bar : h_g = 2770·9 kJ/kg, s_g = 5·8019 kJ/kg-K. *10*

6. (a) A rectangular block of material A (k = 24 W/mK) of 0·10 m thickness is sandwiched between two walls of metals, B (k = 2030 W/mK) of thickness 0·12 m, and C (k = 200 W/mK) of thickness 0·15 m respectively. Heat generation occurs in material A at a uniform rate of $2·5 \times 10^3$ W/m^3. Develop expressions for the steady state temperature distribution in the three layers and determine the maximum temperature and its location in the assembly. The outer surfaces of 'B' and 'C' are maintained at 100°C and 150°C respectively. *10*

(b) (i) An airplane is flying at a speed of 800 kmph at an altitude of 1·5 km, where the air temperature is – 50°C. Find the maximum possible temperature on the airplane skin body. *5*

(ii) A rectangular notch of 0·8 m width and a 90° V-notch are to be used alternately for measuring an expected flow rate of 0·05 m^3/s of a liquid. Find the percentage error that would result in the two cases, if an error of 1 mm is made in the head measurement. Assume C_d = 0·6 for both the notches. *5*

(c) A process equipment has been designed to make heat continuously available at a temperature level of 260°C. The only source of energy is a continuous flow of saturated steam at 17·5 bar (h = 2794·1 kJ/kg; s = 6·3853 kJ/kg-K). Cooling water is also available in large supply at 20°C. The steam is condensed in the equipment and comes out as condensate at 1 bar and 20°C (h = 85·5 kJ/kg; s = 0·2959 kJ/kg-K). How much heat can be transferred from the process to the heat reservoir at 260°C, for every one kg of steam condensed in the process ? *10*

7. (a) (i) Show the various psychrometric processes on a skeleton psychrometric chart. *4*

(ii) Differentiate between the processes of "heating and humidification", 'cooling and humidification" and "adiabatic saturation". What is the change of specific humidity and DBT in each of these processes ? Which of the processes in part (i) are possible in an air-washer ? Explain with a schematic diagram. *6*

(b) (i) Sketch neatly "Moody Diagram' — a chart showing the friction factor, $f = f(Re, E_s / D)$ for full range of Reynolds numbers in pipe flow. Can we use this chart for non-circular conduits ? If yes, how ? *4*

(ii) An oil of density 917 kg/m^3 is being pumped in a 15 cm diameter horizontal pipe. The discharge is measured as 800 litres/minute. The drop in pressure in a stretch of 800 m of pipeline is measured as 95 kPa. Estimate the absolute viscosity of the fluid. *6*

(c) The output of an engine is given as input to an agricultural pumpset. The pump is used for lifting water from a depth of 30 m at the rate of 200 litres/minute. The transmission efficiency between the engine and the pump is 100% and the pump is considered to be 100% efficient. The brake thermal efficiency of the engine is 35%, the calorific value of the fuel is 43 MJ/kg, the cost of fuel is ₹ 53·00 per litre and the density of the fuel is 780 kg/m^3. Estimate the running cost of the fuel for 1000 m^3 of water lifted. *10*

A-GTD-O-NDBB

MECHANICAL ENGINEERING

Paper II

(Conventional)

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.

Answers must be written in ENGLISH only.

Unless otherwise 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. (a) Explain Grashof's linkage. Explain the inversions of this linkage. 4

(b) A single plate clutch is designed to transmit 10 kW power at 2000 rpm. The equivalent mass and radius of gyration of the input shaft are 20 kg and 75 mm respectively. The equivalent mass and radius of gyration of the output shaft are 35 kg and 125 mm respectively.

Calculate :

The time required to bring the output shaft to the rated speed from rest. 4

(c) A 5 cm dia. solid shaft is welded to a flat plate by 1 cm fillet weld. What will be the max. torque that the welded joint can sustain if the permissible shear stress in the weld material is not to exceed 8 kN/cm^2 ? Deduce the expression for the shear stress at the throat from the basic theory. 4

(d) Illustrate International System of Units. 4

(e) Derive equations for compressive and tensile thermal stresses. 4

(f) Draw the schematic of radiographic technique and explain. 4

(g) What are the conditions that would allow a continuous chip to be formed in metal cutting ? 4

(h) What are the different types of fits possible with reference to mechanical systems ? 4

(i) Find the optimal order quantity for a product of which the price breaks are as follows :

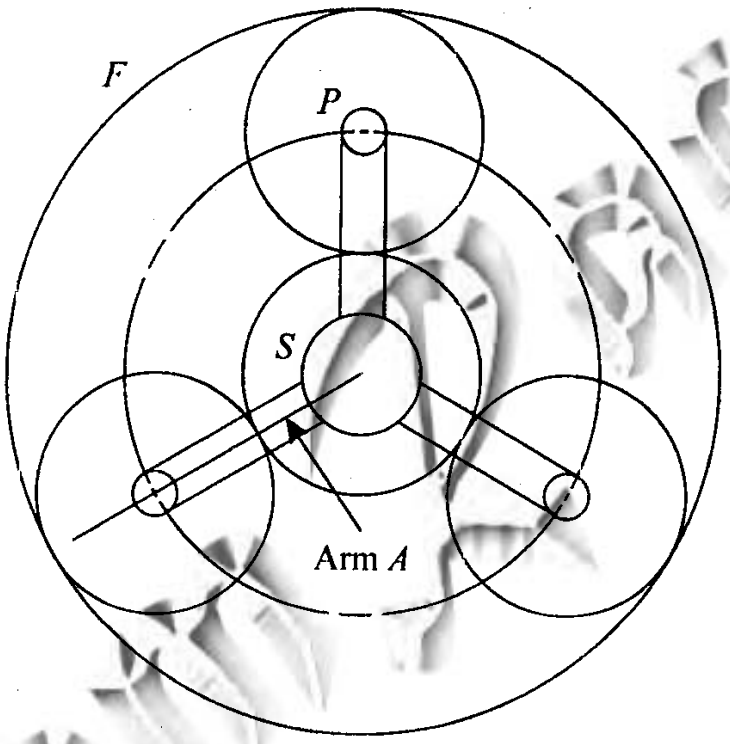
Qty	*Unit Cost*
$0 \leq q_1 \leq 50$	Rs. 10
$50 \leq q_2 \leq 100$	Rs. 9
$100 \leq q_3$	Rs. 8

The monthly demand for the product is 200 units, the cost of storage is 25% of the unit cost and ordering cost is Rs. 20 per order. 4

(j) Define Value Engineering. What are the conditions conductive to take up Value Analysis/ Value Engineering. 4

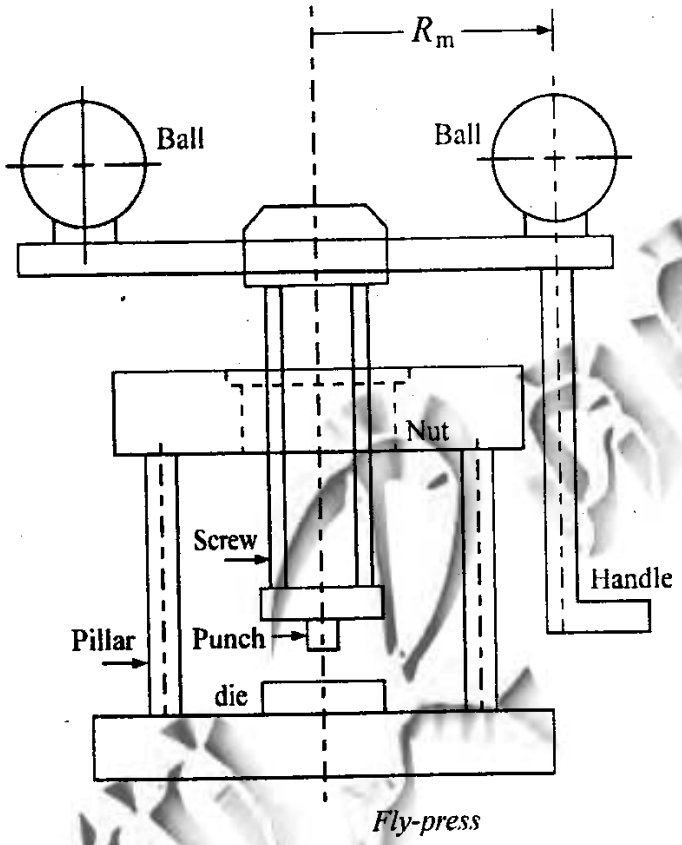
Section – B

2. (a)



In the geartrain shown in the figure, the sun gear S rotates at 500 rpm and the planet carrier A rotates at 100 rpm in the same direction. Determine the number of teeth on each gear and the speed of planet gear P if the diametral pitch of all the gears is 3 teeth/cm and the diameter of the fixed gear F is to be as close to 25 cm as possible. 14

(b)



Fly-press

It is required to design a flypress, as shown in the figure, that is capable of punching 50 mm diameter circles from a 1·5 mm thick mild steel sheet. The ultimate shear strength of the sheet metal is 375 N/mm^2 and it can be assumed that shearing will be complete when the punch penetrates through half the thickness of the sheet. The screw, with square threads, is made of bronze. The factor of safety is 3. The total working stroke consists of a one quarter revolution, 45° in front of the press and 45°

behind the press. During the return stroke, the punch is raised by 5 mm to provide clearance to insert the sheet. The forward or working stroke is completed in 1 sec. The balls are made of cast iron, with a mass density of 7280 kg/m^3 and the radius R_m is 500 mm. Neglecting collar friction, calculate :

(i) The dimensions of the screw,

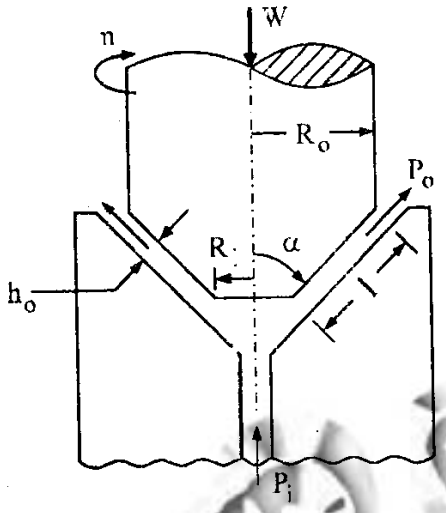
(ii) The length of the nut and

(iii) The size of the balls. 20

(c) A cylindrical pressure vessel 200 cm in diameter and 350 cm in length is made of 1·30 cm thick plates. It is subjected to an internal pressure of 10 kg/cm^2. Calculate the longitudinal and circumferential stresses developed in the vessel. 6

3. (a) The mass of a trailer is 350 kg when empty and 1000 kg when fully loaded. The stiffness of suspension spring is 350 kN/m. The damping factor is 0·5 when fully loaded. The trailer moves at 50 kmph on a road having sinusoidal irregularity of wavelength 4 m. Determine transmissibility when trailer is fully loaded and when empty. 15

(b)



A hydrostatic conical thrust bearing is shown in the figure. Show that the load carrying capacity of the bearing is given by

$$W = \frac{\pi P_i}{2}\left[\frac{R_o^2 - R_i^2}{\log_e\left(\frac{R_o}{R_i}\right)}\right]$$

and the flow requirement is given by,

$$Q = \frac{\pi P_i h_o^3 \sin\alpha}{6\mu \log_e\left(\frac{R_o}{R_i}\right)}$$

15

(c) Explain the concept of real and apparent areas of contact. Write the formula for each. 10

4. (a) A shaft consisting four masses A, B, C and D is in complete balance. The masses A, C and D are 20 kg, 12 kg and 10 kg respectively. The radii of rotations of masses A, B, C and D are 12 cm, 15 cm, 17 cm and 20 cm respectively. The planes of rotation of A and B are 20 cm apart whereas those of B and C are 25 cm apart. The angle between the radii of A and C is 90°. Determine mass at plane B and distance between the planes of C and D. 20

(b) A thin cylinder is turning about its axis. Find the safe number of revolutions for a rotor of 3 metres in diameter if the hoop stress is not to exceed 1300 kg/cm^2. Take density as 6500 kg/cm^3. 10

(c) Explain why corrosion occurs in materials. 10

Section – C

5. (a) Explain expendable pattern casting process with schematic illustration and applications. 10

(b) Differentiate between the working principles of Friction stir welding and Friction welding. 10

(c) Explain salient design principles of milling fixtures with a typical milling fixture diagram. 10

(d) Determine the fundamental deviation and tolerances and the limits of size for hole and shaft pair in the fit : 25 mm H_8–d_9. The diameter steps are 18 mm and 30 mm. The Fundamental deviation for d shaft is given as $-16\ D^{0.44}$. The tolerance unit is, $i = 0.45 * \sqrt[3]{D} + 0.001\ D$. The tolerance grade for number 8 quality is 25 i and for number 9 quality is 40 i. 10

6. (a) Classify the products that are commonly produced by powder metallurgy. Give examples of each. 10

(b) What is the principle of plasma arc welding ? 10

(c) A materials manager adopts the policy to place an order for a minimum quantity of 500 of a particular item in order to avail a discount of 10%. It was found from the company records that for last year 8 orders were placed each of size 200 Nos. Ordering cost is Rs. 500 per order. Inventory carrying charges at 40% cost per unit = Rs. 400. Is the purchase manager justified in his decision ? What is the effect of this decision on the company ? 10

(d) There are four machines W, X, Y and Z. Three jobs A, B and C are to be assigned to the 3 machines out of total 4 machines. The cost of assignment is given below. Find out the optimal assignment.

	W	X	Y	Z
A	18	24	28	32
B	8	13	17	18
C	10	15	19	22

10

7. (a) Explain the principle of Electro Chemical Machining Process with the help of a diagram. 10

(b) The *ABC* company wishes to plan its advertising strategy. There are two medias under consideration, call them Magazine I and Magazine II respectively. Magazine I has a reach of 2500 potential customers. The cost per page of advertising is Rs. 400 and Rs. 600 in Magazine I and II respectively. The firm has a monthly budget of Rs. 6000. There is an important requirement that the total reach for income group under Rs. 20000 per annum should not exceed 4000 potential customers The reach in Magazine I and II for this income group is 400 and 200 potential customers How many pages should be brought in the two Magazines to maximize the total reach ? 15

(c) *XYZ* Ltd carries out *ABC* analysis and has decided to concentrate on *A* item, which total up to the maximum cost of materials. For *A* class items the following data is available :

Annual requirement	=	5000 units
Ordering cost	=	Rs. 500
Carrying cost	=	Rs. 20%
Cost per unit	=	Rs. 80

The company has the following options for purchasing the items.

(i) Place 10 orders of equal size every year.

(ii) Place an order of 1000 units at any time and avail bulk purchase discount of 8%.

(iii) Use *EOQ*

Which options, you think *XYZ* should follow and why ? 15

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