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) For an isentropic expansion of a gas with $C_P = a + kT$, $C_V = b + kT$ and $C_P - C_V = R$, show that $T^b\, v^{a-b}\, e^{kT}$ = constant. 5

(b) A small flexible bag contains 0.1 kg ammonia at-10°C and 3 bar. The bag material is such that the pressure inside varies linearly with volume. The bag is left in open space where the incident solar radiation is 75 W. The heat energy lost to the ground and surrounding in from bag Is at the rate of 25 W. After a while, it is found that the bag is heated to 30°C at which time the pressure ammonia is 10 bar. Estimate (i) the amount of heat energy infiltrated into the bag and (ii) the elapsed time.

Properties of ammonia:

(a) Compressed liquid ammonia at –10°C, 3 bar: specific volume of saturated liquid, V_f = 0.001002 m^3/kg, specific internal energy of saturated liquid, U_f = 134 kJ/kg.

(b) Superheated ammonia vapour at 30°C, 10 bar: specific volume = 0.1321 m^3/kg, specific internal energy = 1347 kJ/kg. 10

(c) Steam enters a 15 cm diameter horizontal pipe as saturated vapour at 5 bar with a velocity of 10 m/s and exit at 4.5 bar and a quality of 0.95. Heat is transferred to surroundings at 300 K from the pipe surface which is at an average temperature of 400 K. Under the steady state operating conditions, determine

(i) the exit velocity.
(ii) the rate of heat transfer from pipe surface in kW.
(iii) the rate of entropy production in kW/K, for the control volume comprising of only pipe and its contents and
(iv) the rate of entropy production for the enlarged control volume that includes pipe, its contents and the immediate surroundings.

Properties of steam at saturation condition:

p	t_{sat}	Sp. volume, m^3/kg		Sp. enthalpy, kJ/kg		Sp. entropy, kJ/kg-K	
bar	°C	liquid (v_f)	vapour (v_g)	liquid (h_f)	vapour (h_g)	liquid (S_f)	vapour (S_g)
4.5	147.93	0.001088	0.4140	623.5	2744	1.8207	6.8565
5.0	151.86	0.001093	0.3749	640.0	2749	1.8607	6.8213

10

(d) (i) A certain gas obeys the equation of state, $P(v - a) = RT$. Show that the ratio of its volume expansivity, β with that of an ideal gas, β_{ideal} and the ratio of its isothermal compressibility, K_T with that of an ideal gas, $K_{T;\,ideal}$ are given by

$$\frac{\beta}{\beta_{ideal}} = \frac{RT}{RT + ap} \text{ and}$$

$$\frac{K_T}{K_{T,ideal}} = 1 - \left(\frac{a}{v}\right)$$

(ii) For a substance with volume expansivity, $\beta > 0$, show that at every point of a single phase region (vapour region) on a Mollier diagram, the slope of constant pressure line is greater than the slope of constant temperature line but less than that of constant volume line. 6 + 9

2. (a) Explain with neat sketch, the working principle of a hybrid rocket engine. What are advantages of this engine? 10

(b) What are the different types of combustion chambers in C.I. engine? Explain with a neat sketch, an open combustion chamber. What are the merits and demerits of the open combustion chamber? 10

(c) A four stroke single cylinder petrol engine mounted on a motor cycle was put to load test. The load measured on dynamometer was 30 kg with drum diameter and speed respectively at 900 mm and 2000 rpm. The engine consumed 0.15 kg of fuel in one minute, the calorific value of fuel being 43.5 MJ/kg. The fuel supply to the engine was stopped and was driven by a motor which needed 5 kW of power to keep it running at the same speed, the efficiency of the motor being 80%. The engine cylinder bore and stroke are respectively at 150 mm and 200 mm. Calculate

(i) brake power,
(ii) Indicated power,
(iii) mechanical efficiency,
(iv) brake thermal efficiency,
(v) Indicated thermal efficiency,
(vi) brake mean effective pressure and
(vii) Indicated mean effective pressure. 10

(d) The overall thermal efficiency of a 5 MW nuclear power plant for a submarine is 30%. Calculate the amount of natural uranium, U^{235}, needed to generate the power it the average energy release per fission of U^{235} is 190 MeV. Take 1 W = 6.241×10^{12} MeV/s. Avogadro's Number is 6.02×10^{23}. 10

3. (a) Cooling water at a steady rate of 0.5 kg/s flows through an inner tube having inner diameter of 25 mm and length of 10 m of a tube-in-tube condenser. The mean inlet temperature of cooling water is 10°C. Saturated steam condenses in the annulus at a uniform rate such that the inner surface temperature of the tube is constant throughout the length of the tube at 40°C. The average condensing side heat transfer coefficient is 10000 W/m^2-K. Neglect the thickness of the heat exchanger tube. Calculate the effectiveness of the heat exchanger and the exit water temperature.
Properties of water are given below:
Specific heat = 4180 J/kg-K,
Density = 990 kg/m^3,
Dynamic viscosity = 0.8×10^{-3} Pascal.sec,
Thermal conductivity = 0.57 W/m-K
You may use the relation, $Nu = 0.023\ Re_d^{0.8}\ Pr^{0.4}$. 15

(b) The net radiation from the surfaces of two parallel plates having equal emissivities of 0.8 and at different temperatures of T_1 and T_2 ($T_1 > T_2$) is to be reduced by 99%. How many numbers of radiation screens having equal emissivities of 0.05 are to be placed between the plates to achieve the reduction in heat exchange? 15

(c) What is an expansion device? Explain with the help of a neat sketch the working principle of a Thermostatic Expansion Device (TEV). 10

4. (a) An R-12 vapour compression plant producing 10 tonnes of refrigeration operates with condensing and evaporating temperatures of 35°C and –10°C

respectively. A suction line heat exchanger is used to subcool the saturated liquid leaving the condenser. Saturated vapour leaving the evaporator is superheated in the suction line heat exchanger to the extent that a discharge temperature of 60°C is obtained after isentropic compression. Calculate

(i) The subcooling achieved in the heat exchanger,
(ii) The refrigerant flow rate in kg/s,
(iii) The cylinder dimensions of the two-cylinder compressor, if the speed is 900 rpm, stroke - to –bore ratio is 1 : 1 and the volumetric efficiency is 80%,
(iv) The COP of the plant and
(v) The power required to drive the compressor in kW.

Draw the cycles on P-h and T-s diagrams. You may use the following table:

Temperature	Specific Volume	Specific enthalpy		Specific entropy	
(°C)	(m^3/kg)	KJ/kg		KJ/kg-K	
	Vapour (v_g)	Liquid (h_f)	Vapour (h_g)	Liquid (S_f)	Vapour (s_g)
–10	0.0766	190.88	347.13	0.9660	1.5600
+ 35	0.0206	233.50	365.92	1.1139	1.5419

Average specific heat of desuperheating vapour at condenser = 0.796 KJ/kg-K. Average specific heat of vapour between evaporator outlet and compression suction = 0.658 KJ/kg-K. 20

(b) A rectangular fin of length 30 cm, width 30 cm and thickness 2 mm is attached to a surface at 300°C. The fin is made of aluminum (K = 204 W/m-K) and is exposed to air at 30°C. The fin end is uninsulated and can lose heat through its end also. The convective heat transfer coefficient between the fin surface and air is 15 W/m^2-K. Determine:

(i) The temperature of the fin at 30 cm from the base,
(ii) The rate of heat transfer from the fin and
(iii) Fin efficiency. 10

(c) Briefly describe the various methods of air -conditioning duct design. 10

5. (a) A tank with the vertical sides measuring 3m × 3m contains water In a depth of 1.2 m. An oil of density 900 kg/m^3 was poured in the tank up to a depth of 0.8 m. The vertical wall can withstand the thrust of 58 kN. Calculate the actual thrust on the wall and centre of pressure. If the oil level is increased up to 0.9 m, what will be stability of the wall? 10

(b) For a rate of flow exceeding certain value, the coefficient of discharge for a venturimeter used for measuring the discharge of an incompressible fluid is found to be constant. Prove that the loss of head in the convergent portion of the venturi can be expressed as KQ^2 under these conditions, where K is a constant (function of c_d, areas of the venturimeter) and Q is flow rate in m^3/s. What will be the value of K, assuming the c_d constant. 10

(c) A straight inclined pipeline 300 m long discharges freely at a point 50 m lower than the water surface at intake. The pipe intake projects into the reservoir (k_e = 0.8). The first 200 m of the pipe is 350 mm diameter and the remaining 100 m is of 250 mm diameter (k_c = 0.21),

(i) Find the rate of discharge assuming f = 0.06.
If the junction point C of the two sizes of the pipe is 40 m below the intake water surface level, find the pressure head.
(ii) just upstream of C and
(iii) just downstream of C.
Assume sudden contraction at C.
(iv) Verify the head loss across contraction C. 10

(d) Two pipes have length L each. One of them has a diameter of D and other d. If the pipes are arranged in parallel, the head loss is h for a discharge of Q m^3/s. When the pipes are connected in series, the head lost is H for same discharge. Find the ratio of H to h, for $D = 2.25d$. (All dimensions in m) 10

6. (a) Develop (in general terms) an expression for the per cent of error in Q over a triangular weir if there is a small error in the measurement of the vertex angle. Assume there is no error in the weir coefficient. Compute the per cent error in Q, if there is a 1° error in the measurement of total vertex angle of a triangular weir which is having a total vertex angle of 60°. 10

(b) What is the hydraulic jump in the flow in open channel? What are its types and characteristics with respect to Froude's number of flow? 10

(c) Air flows isothermally in a long pipe. At one section the pressure is 600 kPa abs, the temperature is 25°C and the velocity is 30 m/s. At a second section (at some distance from the first section) the pressure is 100 kPa abs. Find the energy head loss due to friction and determine the thermal energy that must have been added to or taken from the fluid between the two sections. Assume the diameter of pipe to be constant. 10

(d) Researchers plan to test a 1 : 13 model of a ballistic missile in a high speed wind tunnel. The prototype missile will travel at 380 m/s through air at 23°C and 95.0 kPa (abs).

(i) lf the air In the wind tunnel test section has a temperature of –20°C at a pressure of 89 kPa (abs), what must Its velocity be? and

(ii) Estimate the drag force on the prototype if the drag force on the model is 400 N. 10

7. (a) Explain the effect of vane angle on manometric efficiency in a centrifugal pump. Why is vane angle in a centrifugal pump not kept at values below 20°? 10

(b) Fluid flow, with a velocity of V_∞ over a flat plate located at y =0. The leading edge of the plate is located at x = 0. The possible velocity profiles in the boundary layer having thickness $\delta(x)$ are as follows:

(i) $$\frac{u}{V_\infty} = 2\frac{y}{\delta} - \left(\frac{y}{\delta}\right)^2$$

(ii) $$\frac{u}{V_\infty} = \frac{3}{2}\frac{y}{\delta} - \frac{1}{2}\left(\frac{y}{\delta}\right)^3$$

(iii) $$\frac{u}{V_\infty} = \frac{y}{\delta} - \frac{1}{2}\left(\frac{y}{\delta}\right)^2$$

Find out which of these velocity profiles are feasible for laminar flow. Also, identify the smoothest velocity profile from these three options. 10

(c) Describe with neat sketch, the construction and working principle of Rotometer. What are its advantages? 10

(d) A single acting reciprocating pump lifts a liquid of specific weight 9.0kN/m^3 from a pressurized storage reservoir to an overhead container. The free surface in the supply reservoir is at an elevation of 3.5 m above the centre of the pump. The ambient pressure over the liquid surface in the supply reservoir is 27kN/m^2 (vacuum). The other relevant data relating to the pump are as follows:
Length of the suction pipe = 6.0 m;
Diameter of suction pipe = 10 cm;
Minimum pressure anywhere in the system = 27kPa (abs)
Length of stroke = 50 cm;
Diameter of cylinder = 20 cm;
Atmospheric pressure = 99 kN/m^2 (abs)
Determine the maximum speed admissible in rpm. 10

8. (a) Define air rate, specific power and the cycle work ratio in a gas turbine. What is the significance of these parameters? 5

(b) Justify the selection of a turbine runner with highest specific speed possible. Derive an expression for the specific speed of a pelton wheel, for speed ratio 0.46, overall efficiency 85% and co-efficient of velocity of nozzle 0.98. 10

(c) What are the shortcomings of a fire tube boiler restricting it for limited use?

How are the impurities in feed water removed from the boiler? 10

(d) What are the constructional features of an axial flow compressor? How air is compressed and what is the method of getting higher compression ratio in such compressor? 5

(e) A gas turbine utilizes two-stage centrifugal compressor. The pressure ratios for the first and second stages are 2.5 and 2.1 respectively. The flow of air is 10 kg/s, this air being drawn at 1.013 bar and 20°C. If the temperature drop in the intercooler is 60°C and the isentropic efficiency is 90% for each stage, calculate:
(i) the actual temperature at the end of each stage and
(ii) the total compressor power.
Assume γ = 1A and C_p = 1.005 kJ/kg K for air. 10

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.

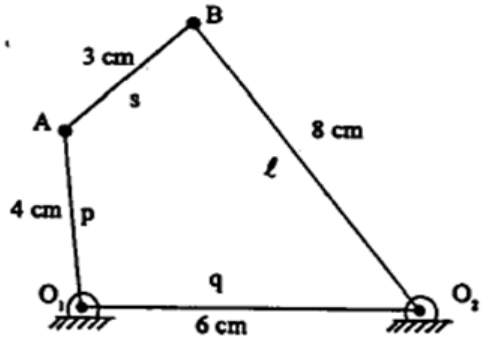
Attempts of questions shall be counted in chronological order. Unless struck off, attempt of a question shall be counted even if attempted partly.

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) Determine the maximum and minimum transmission angle of the mechanism shown which is driven by member O_1A.



(b) For a cam whose acceleration is constant and is rotating with a constant speed, plot and show displacement diagram, velocity diagram, acceleration diagram and jerk diagram during rise.

(c) What is the effect of V belt over flat belt in transmission? How to avoid slip in flat belt?

(d) What are Lang lay and Regular lay wire ropes? Explain.

(e) Fine pitch threads are more resistant to loosening due to vibrations than coarse pitch threads, why?

(f) What is the difference between thick film lubrication and thin film lubrication?

(g) Differentiate between basic static load rating and basic dynamic load rating of a ball bearing.

(h) Differentiate clearly between Yield stress and 0.2 % proof stress for a ductile metal.

(i) At a point in a stressed body, principal strains are ε_1 and ε_2. If E is the Young's modulus and μ is the Poisson's ratio, write down expressions for principal stresses in terms of ε_1, ε_2, E and ν.

(j) A close coiled helical spring is subjected to axial load. Shear stress is developed in spring wire. Why the resultant shear stress at inner coil radius is more than the resultant shear stress at outer coil radius?

(k) Mark the plane with Miller Indices (1 $\bar{1}$ 0) in a cubic structure.

(l) What is lead - tin eutectic alloy? What are special characteristics of a eutectic alloy? What is the composition of solder used in joining electrical connections?

(m) What types of oxyacetylene flames you will use to weld (i) Copper base metals (ii) High carbon steel? Why are all fuel lines threaded left handed?

(n) Write the advantages and disadvantages of climb milling. In connection with

grinding define grinding ratio.

(o) In connection with surface texture define (a) waviness (b) flaws, and (c) lay. List three defects found on surfaces.

(p) Name and explain very briefly the steps in Value Analysis.

(q) Name and differentiate very briefly the principal classes of methods used in forecasting of demand.

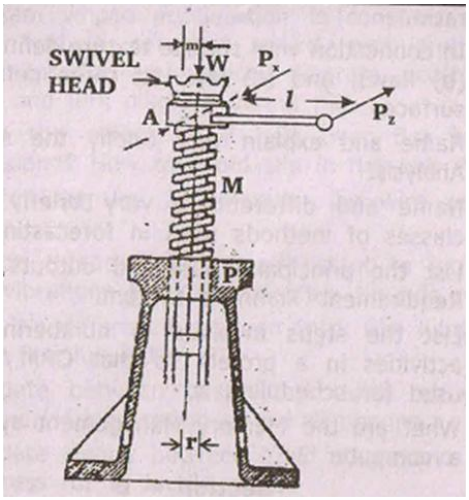
(r) List the principal inputs and outputs of a Material Requirement Planning System.

(s) List the steps involved in numbering events and activities in a project so that CPM / PERT can be used for scheduling it.

(t) What are the Memory Management systems used in a computer?

SECTION—B

2. (a) The following particulars refer to a screw jack shown in Figure below:
Vertical load on the screw W = 20,000 N
Force applied at the lever end whose length l = 80 cm
Mean radius of the screw r = 2.5cm
Pitch of the screw p = 1 cm
Mean radius of contact surface between swivel & head r_m = 4 cm
Coefficient of friction between screw thread and bearing μ' = 0.15
Coefficient of friction between the swivel head and bearing μ = 0.1



Determine:
(i) The force on the lever end required while raising and lowering the load.
(ii) The efficiency of the screw jack in both cases. 12

(b) A rotor of mass 10 kg is mounted midway on a 20 mm diameter horizontal shaft supported at the ends by two bearings. The bearing span is 0.8 m. Because of manufacturing defect the center of gravity of the disc is 0.1 mm away from the geometric center of the rotor. If the system rotates at 3000 rpm, determine the amplitude of the steady state vibration and the dynamic force transmitted to the bearing. Take $E = 2 \times 10^6$ bar. 20

(c) Write short notes on the following:
(i) Epicyclic gear trains.
(ii) Interference and undercutting in Involute gears. 8

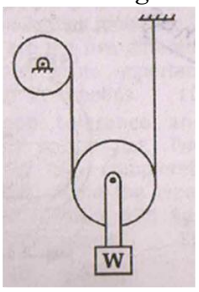
(d) What are metal matrix composites? What are special characteristics of these composites? What are the reinforcing materials? What are the applications of MMC? 10

3. (a) An open belt system is transmitting 10 kW power. Driving pulley is of diameter 200 mm and driven pulley is of diameter 480 mm. Centre distance between the pulleys is 2 m. Maximum stress in belt is not to exceed 2.2 MPa. Thickness of the belt is 8 mm. Determine breadth and length of the belt.
Given density of belt material = 950 kg/m^3
Coefficient of friction between belt and pulley = 0.3.

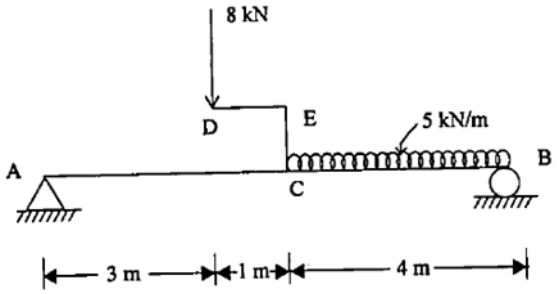
Driving pulley is rotating at 1000 rpm.
Neglect bending stress in belt. 20

(b) What are different types of threads used for power transmission? Make a simple sketch of each. Give special features of each thread and their applications. 10

(c) Fatigue life of a 6 × 37 wire rope of nominal diameter of 12 mm is to be achieved to be 0.2 billion bends. Tensile stress designation of wire rope is 1960 MPa. How much load can be lifted through a sheave of diameter 400 mm, through the arrangement shown in figure? Take ratio of bearing pressure between rope and sheave to ultimate strength of rope = 0.0024. 10

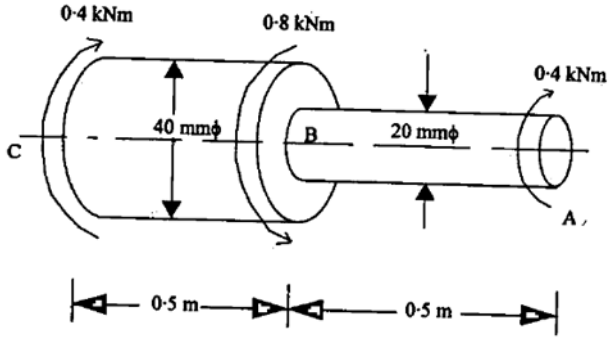


4. (a) A beam AD, 8 m long hinged at end A and roller supported at end B carries a point load of 8 kN at crank ED = 1 m, and a uniformly distributed load of 5kN/m over CB = 4m.



Determine:
(i) reactions at ends.
(ii) bending moment at section where SF is zero.
(iii) Draw BM diagram only. 20

(b) A stepped shaft ABC, 1 m long made of steel is of diameter 20 mm from A to B = 0.5 m, 40 mm from B to C = 0.5 m. It is subjected to twisting moments 0.4 kNm (cw) at A, 0.8 kNm (ccw) at B and 0.4 kNm (cw) at C.
If G = 84kN/mm² determine angular twist between A to C. 10



(c) What do you understand by tempering? What are martempering and austempering processes? What are their special features? 10

SECTION—C

5. (a) Write two causes of cold cracks in welded joints. Write the carbon equivalent formula and describe its importance in welding. Why preheat is required in welding? A machine rated at 100 A at 60% duty cycle is accelerated to 160 A. Find the percentage reduction of the output cycle. 10

(b) Name the various tests to be performed for moulding sand. Draw a top gate and

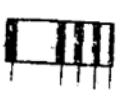
write its advantages. What is a misrun and how is it caused? Write some advantages of cupola. 10

(c) Define mistooling and its effectiveness. Draw a fig. showing relative severity of the following machining operations qualitatively: Broaching (internal), milling, gear shaping and drilling, boring. What happens to drilling if the lip relief angle is too small? Too large? In grinding, explain the meaning of the terms, loading and truing. 10

(d) Write a FORTRAN program to find average height of boys in a class. 10

6. (a) Briefly describe some of the similarities between a robot and an NC machine. What are the five different types of robot systems? Discuss some important aspects of pendant programming in robotics. 10

(b) Explain the difference between tolerance and allowance. Write in short about optical flat. Two fringe patterns are supplied for two completely different surfaces using optical flat, name the types of surfaces, and draw if required. Discuss with fig., principle of working of a pneumatic gauge. 10



Fringe patterns for two completely different types of surfaces.

(c) Write the process variable', in wire drawing. In forging define the terms (i) Edging and (ii) Fullering and (iii) Flash. How are the seamless tubes produced? 10

(d) Explain with fig a drill - jig mentioning various provisions. What is the difference between FMS and FMC? Write some disadvantages of FMS. 10

7. (a) A unit manufactures 50,000 bottles of tomato Ketchup In a year. The factory cost per bottle is Rs. 6, the set up cost per production run is estimated to be Rs. 90 and the carrying cost on finished goods inventory are 20% of the cost per annum. Production rate is 600 bottles per day and sales are expected at 150 bottles/day.

(i) Derive an expression for lot size that will give minimum cost. 10

(ii) What is the optimum lot size? 5

(iii) What is the number of runs required per year? 5

(iv) What will be the total cost per year if the number of runs has to be an integer? 5

(b) Ghosh and Company making pipes is considering investment in an aggressvie advertising campaign for the next year's sales.

The data for the last year 2009-10 is:

Variable Expenses	
Direct Material	Rs. 3.25 per piece
Direct Labour	Rs. 8.00 per piece
Variable overhead	Rs. 2.50 per piece
	Rs. 13.75 per piece
Fixed Expenses:	
Manufacturing	Rs. 25,000
Selling	Rs. 40,000
Administrative	Rs. 70,000
Total Fixed	1,35,000
Selling price per pipe	Rs. 25
Sales 2009- 10 (20,000 units)	Rs. 5,00,000

The sales target for 2010-11 is Rs. 5,50,000:

(i) What is the profit and break even point for the year 2009-10? 7

(ii) How will the BEP change if the company spends Rs. 11,250 on advertising in 2010-11? 4

(iii) What will be the profit if the company is able to sell 21,000 pipes only in 2010-11? 4