MODEL QUESTION PAPER - 2

Geotechnical Engineering

Time: 3 Hour *Max.Marks: 75*

PART-A

I. Answer all questions in one word or one sentence (9 x 1 = 9 Marks)

Sl. No	Question
1	The biggest size of clay particle is
2	The ratio of the volume of voids to the total volume of soil
3	The falling head method of determination of coefficient of permeability is best suited for
4	The grain size distribution curve is plotted between size of particles and
5	The shear strength equation for a purely cohesionless soil.
6	Define optimum moisture content
7	Define consolidation of soil
8	List any two geophysical methods of soil exploration
9	Give two examples of shallow foundation

PART-B

II. Answer any eight questions from the following. Each question carries 3 marks.

(8 x 3 = 24 Marks)

1	Define consistency limits of soil.
2	State Darcy's law of permeability and define co-efficient of permeability.
3	Detail the various factors affecting permeability
4	Describe Mohr-Coulomb failure theory
5	Detail the procedure for conducting Standard Proctor test for determining the compaction characteristics of soil.
6	List the factors affecting compaction
7	Define the three stages of consolidation
8	Define disturbed and undisturbed samples.

9	List the objectives of site investigation.
10	List the various assumptions in Terzaghi's bearing capacity theory.

PART-C

Answer ALL questions. Each question carries 7 marks. (6 x 7 = 42 Marks)

III	One cubic meter of wet soil weighs 19.8 kN. If the specific gravity of particles is 2.7 and water content is 11%, find the void ratio, dry density and degree of saturation.
OR	
IV	Two soils were tested for their consistency limits in the laboratory. The following data were obtained. Soil A: Liquid limit = 38%; Plastic limit = 25%; Natural moisture content (measure in field) = 40% Soil B: Liquid limit = 60%; Plastic limit = 30%; Natural moisture content (measure in field) = 50% Which soil has greater plasticity? Which soil is more compressible?
V	The following data were recorded in a constant head permeability test. Internal diameter of permeameter = 7.5 cm Head lost over a sample length of 18 cm = 24.7 cm Quantity of water collected in 60 s = 626 ml Calculate the coefficient of permeability of the soil sample.
OR	
VI	In an in-situ vane shear test on a saturated clay, a torque of 0.035 Nm was required to shear the soil. The diameter of the vane was 50 mm and length 100 mm. Calculate the undrained shear strength of the clay.
VII	Explain the procedure for determining the bearing capacity by conducting plate load test.
OR	
VIII	Discuss the different stages of sub-surface exploration.
IX	Differentiate between the compaction curves of sand and clay.
OR	
X	Differentiate between compaction and consolidation
XI	The pavement of a road on a level ground is to be laid on a base course 400 mm thick, consisting of a course-grained gravel-sand mixture with good draining properties, placed evenly on an impervious subgrade. The porosity of the gravel-sand is 40% and the degree of saturation, 60%. There is a sudden downpour during construction work. Assuming that all water immediately infiltrates into the ground, calculate the rainfall in mm that would saturate the base course to its full thickness
OR	

Data table for question IV:

Soil A	Soil B
Liquid limit = 38%	Liquid limit = 60%
Plastic limit = 25%	Plastic limit = 30%
Natural moisture content (measure in field) = 40%	Natural moisture content (measure in field) = 50%

XII	An airport runway fill needs 600000 m^3 of soil compacted to a void ratio of 0.75. There are two borrow pits A and B from where the required soil can be taken and transported to the site.
XIII	Choose and describe the different types of boring that can be adopted in rocks.
OR	
XIV	Determine the ultimate bearing capacity of a strip footing, 1.5 m wide, with its base at a depth of 1 m, resting on a dry sand stratum. Take, γ_d=17kN/m^3, $\phi = 38^0$ (Nq = 60, N_γ = 75) and C = 0. Use Terzaghi's theory.

Table in XII:

Borrow pit	In-situ void ratio	Transportation cost
A	0.80	Rs. 10/m^3
B	1.70	Rs. 5/m^3

Which of the two borrow pits would be more economical? (XII)

MODEL QUESTION PAPER – 1 ANSWER KEY

Geotechnical Engineering

Time: 3 Hour *Max.Marks: 75*

PART-A

I. Answer all questions in one word or one sentence (9 x 1 = 9 Marks)

Sl. No	Answers	Split-up Mark	Total Marks
1	0.002 mm		1
2	Porosity		1
3	Cohesive soil (Clayey soil)		1
4	Percentage finer by weight		1
5	$S = \sigma \tan \phi$		1
6	The water content corresponding to the maximum dry unit weight is termed as optimum moisture content		1
7	Reduction in volume of soil due to the expulsion of water under gradually applied load.		1
8	Seismic refraction method Electrical resistivity method		1
9	Strip footing Spread footing		1

PART-B

II. Answer any eight questions from the following. Each question carries 3 marks.

(8 x 3 = 24 Marks)

1	**Consistency** of a fine-grained soil is the physical state in which it exists. It is used to denote the degree of firmness of soil. Fine-grained soil can exist in four states namely, liquid, plastic, semi-solid and solid states. The water contents at which the soil changes from one state to the other are known as consistency limits or Atterberg's limits. The three consistency limits of soil are liquid limit, plastic limit and shrinkage limit. **Liquid limit** is the water content at which the soil changes from the liquid state to plastic state. **Plastic limit** is the water content below which the soil stops behaving as a plastic material. At this water content the soil loses its plasticity and passes to a semi-solid state. **Shrinkage limit** is the smallest water content at which the soil is saturated. It is defined as the maximum water content at which a reduction of water content will not cause a decrease in the volume of	1 1 1	3

	the soil mass.		
2	The flow of free water through soil is governed by Darcy's law. Darcy's law states that for laminar flow in a homogeneous soil, the velocity of flow (v) is directly proportional to the hydraulic gradient (i) $v \alpha i$ introducing the coefficient of proportionality, k $v = k\ i$ but, $v = q/A$, where q = discharge and A = cross-sectional area $q = k\ iA$ k, the coefficient of proportionality is the Coefficient of Permeability which is defined as the velocity of flow which will occur under unit hydraulic gradient.	1 1 1	3
3	Factors affecting permeability of soil are: • Particle size Coefficient of permeability is proportional to the square of the particle size. Permeability of coarse-grained soils is very large compared to fine-grained soils. • Structure of soil mass For the same void ratio, permeability is more for flocculated structure than dispersed structure. • Shape of particles Angular particles have greater surface area when compared to rounded particles. Therefore angular particles are less permeable than rounded particles. • Void ratio Coefficient of permeability varies as $e^3/(1+e)$, therefore, for a given soil greater the void ratio, the higher is the value of coefficient of permeability. • Properties of water Coefficient of permeability is directly proportional to the unit weight of water and inversely proportional to its viscosity. As temperature varies there will be large variation in viscosity, and hence coefficient of permeability increases with an increase in temperature due to the reduction in viscosity. • Degree of saturation If the soil is not fully saturated, there will be entrapped air and the presence of air in soils blocks the passage thus reducing the permeability. • Adsorbed water The adsorbed water attached to the surface of fine-grained soils causes an obstruction to flow of water in the pores, thereby reducing the permeability of soil. • Impurities in water Any foreign matter in water has a tendency to plug the flow passage and reduce the effective voids and hence the permeability.	Any 6	3

4	Soil is a particulate material. The shear failure occurs in soils by slippage of particles due to shear stresses. The failure is by shear, but the shear stresses at failure depends on the normal stresses on the potential failure plane. Thus, according to Mohr-Columb theory, the failure is caused by a critical combination of the normal and shear stresses. The soil fails when the shear stress on the failure plane at failure, (τ_f) is a unique function of the normal stress, (σ) acting on that plane. $\tau_f = f(\sigma)$ The shear stress on the failure plane at failure is defined as the shear strength of soil, 'S' $S = f(\sigma)$ A plot can be made between the shear stress and normal stress at failure, and so obtained curve is termed as Mohr envelope. Failure of the soil occurs when the Mohr circle of the stresses touch this Mohr envelope. Any Mohr circle which does not touch the Mohr envelope and lies below it represents a non-failure condition. The curved Mohr envelope was replaced by a straight line by Coulomb, and shear strength of a soil at a point on a particular plane was expressed as a linear function of the normal stress as, $S = C + \sigma \tan \phi$ The component, C of the shear strength is known as cohesion. Cohesion holds the soil particles together as a soil mass and is independent of the normal stress. The angle ϕ is called the angle of internal friction. It represents the frictional resistance between the soil particles, which is directly proportional to the normal stress, σ	1 1 1	3
5	The test consists of compacting soil at various water contents in the mould, in three equal layers, each layer being given 25 blows of the 2.6 kg rammer dropped from a height of 310 mm. The dry density obtained in each test is determined by knowing the mass of the compacted soil and its water content. IS: 2720 (Part VII) 1980/87recommends a mould of 1000 ml capacity with an internal diameter of 100 mm and an internal effective height of 127.5 mm.	1 1 1	3
6	Factors affecting compaction: • Water content At low water content, the soil is stiff and offers more resistance to compaction. As the water content is increased, the soil particles get lubricated. The soil mass becomes more workable and the particles have closer packing. The dry density of the soil increases with an increase in the water content till the optimum water content in reached. • Amount of compaction The compaction of soil increases with the increase in amount of compactive effort. With increase in compactive effort, the optimum water content required for compaction also decreases. • Types of soil The compaction of soil depends upon the type of soil. In general, coarse grained soils can be compacted to higher dry density than fine-grained soils.	Any 3	3

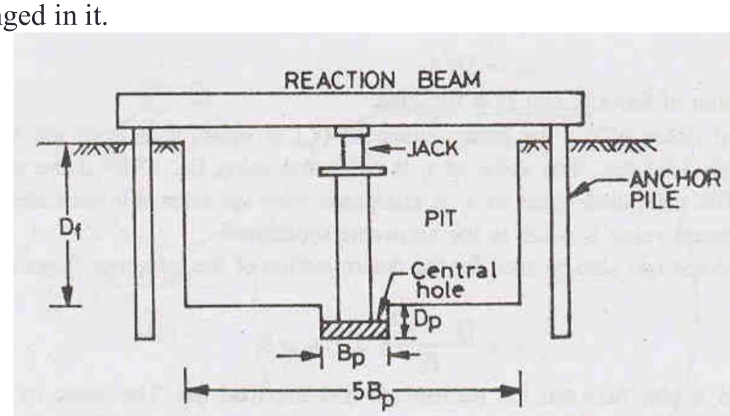
	• Methods of soil compaction The dry density achieved depends not only upon the amount of compactive effort but also on the method of compaction. For the same amount of compactive effort, the dry density will depend upon whether the method of compaction utilizes kneading action, dynamic action or static action.		
7	Compression of a saturated soil under a steady static pressure is known as consolidation. It is entirely due to expulsion of water from the voids. The consolidation of a soil deposit can be divided into 3 stages: 1. Initial consolidation It is the reduction in volume of soil just after the application of load. In partially saturated soils thus decrease in volume is due to expulsion and compression of air in voids and also due to the compression of solid particles. For saturated soils initial consolidation is mainly due to compression of solid particles. 2. Primary consolidation After initial consolidation, further reduction in volume occurs due to expulsion of water from voids. This decrease in volume depends on permeability of soil and hence is time dependent. In fine-grained soils primary consolidation occurs over a long time, but in coarse-grained soils it occurs rather quickly due to high permeability. 3. Secondary consolidation Reduction in volume continues at a very small rate even after the excess hydrostatic pressure developed by applied pressure is fully dissipated and the primary consolidation is complete. This additional reduction in volume is secondary consolidation.	1 1 1	3
8	Disturbed samples are the samples in which the natural structure of the soil gets disturbed during sampling. But these samples represent the composition and the mineral content of the soil. Disturbed samples can be used to determine the index properties of soil. Undisturbed samples are the samples in which the natural structure of the soil and the water content are retained. It is impossible to get truly undisturbed samples, as some disturbance is inevitable during sampling. Undisturbed samples are used for determining the engineering properties of soil, such as compressibility, shear strength and permeability. The smaller the disturbance, greater would be the reliability of the results.	1.5 1.5	3
9	• To select the type and depth of foundation for a given structure. • To determine the bearing capacity of soil. • To estimate the probable maximum and differential settlement. • To establish the ground water level. • To predict the lateral earth pressure against retaining walls and abutments. • To select suitable construction techniques. • To predict and solve potential foundation problems. • To ascertain the suitability of soil as a construction material.	Any 6	3

	• To investigate the safety of the existing structures and to suggest remedial measures.		
10	The various assumptions in Terzaghi's bearing capacity theory are: • The base of footing is rough • The footing is laid at a shallow depth • Shear strength of soil above the base of the footing is neglected. The soil above the base is replaced by a uniform surcharge. • The load on the footing is vertical and is uniformly distributed. • The footing is long, strip footing • The shear strength of soil is governed by Mohr-Coulomb equation.	All 6	3

PART-C

Answer ALL questions. Each question carries 7 marks. (6 x 7 = 42 Marks)

III	Unit weight of soil, γ = 19.8 kN/m^3 Specific gravity, G = 2.7 Water content, w = 0.11 Dry unit weight, $\gamma_d = \frac{\gamma}{1+w} = \frac{19.8}{1+0.11} = 17.83$ kN/m^3 $1 + e = \frac{G\gamma_w}{\gamma_d} = \frac{2.7 \, X \, 9.81}{17.83} = 1.48$ Void ratio, e = 0.48 Degree of saturation, $S = \frac{w\,G}{e} = \frac{0.11 \, X \, 2.7}{0.48} = 0.618 = 61.8\%$	3 2 2	7
OR			
IV	Plasticity index, $I_p = w_L - w_p$ Plasticity index of soil A = 38 – 25 = 13 Plasticity index of soil B = 60 – 30 = 30 I_p of soil B is more, therefore Soil B has a higher degree of plasticity. Compressibility is a direct function of liquid limit. Soil with w_L = 60% is more compressible than soil with w_L = 38%. Therefore, soil B is more compressible.	2 1 1 1 1 1	7
V	Internal diameter of permeameter, d = 7.5 cm C/s area of permeameter, $A = \pi\frac{d^2}{4} = \pi\frac{7.5^2}{4} = 44.18\ cm^2$ Length of the sample, l = 18 cm Head lost over a sample = 24.7 cm Quantity of water collected (in t = 60 s) = 626 ml $k = \frac{Ql}{Ath} = \frac{626 \, X \, 18}{44.18 \, X \, 60 \, X \, 24.7} = 1.72 \, X \, 10^{-1} cm/s$	Eqn – 4 Ans - 3	7
OR			

VI	The height of the vane, h = 100 mm = 0.1 m The diameter of the vane, d = 50 mm = 0.05 m The maximum torque applied, T = 0.035 Nm. Undrained shear strength of clay, C_u =? $$T = C_u \pi (\frac{d^2 h}{2} + \frac{d^3}{12})$$ $$0.035 = C_u \pi (\frac{0.05^2 X 0.1}{2} + \frac{0.05^3}{12})$$ C_u = 82.27 N/m^2	Eqn -3 Subs - 2 Ans- 2	7
VII	Plate load test is done at site to determine the ultimate bearing capacity of soil and settlement of foundation under the loads for clayey and sandy soils. So, plate load test is helpful for the selection and design the foundation. To calculate safe bearing capacity suitable factor of safety is applied. A pit is excavated in the ground at which foundation is to be laid. The size of pit is generally 5 times the size of the plate. The depth excavated should be equal to proposed foundation depth. The plate used is made of mild steel. It may be square (0.3m x 0.3m) or circular (0.3m diameter) with 25mm thickness. After excavation of pit, at center of excavated pit steel plate sized hole is excavated and the plate is arranged in it.  After arranging the plate in central hole hydraulic jack is arranged on top of plate to apply load. Reaction beam or reaction trusses is provided for the hydraulic jack to take up the reaction. Otherwise, a loaded platform is created (using sand bags etc.) on the top of hydraulic jack and provided the reaction. After that seating load is applied to set the plate and released after some time. Now load is applied with an increment of 20% of safe load. Dial gauges are arranged at bottom to record the settlement values. At 1min, 5min, 10min, 20min, 40min, and 60min and after that for every one-hour interval the settlement is observed and noted. The observations are made until the total settlement of 25mm has occurred. The load -settlement curve is plotted and from that bearing capacity is calculated.	Fig – 3 Expl - 4	7

OR

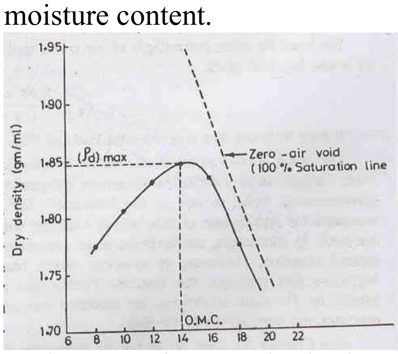
<table>
<tr><td>VIII</td><td>Sub-surface explorations are carried out in 3 stages:
1. Reconnaissance
2. Preliminary exploration
3. Detailed exploration
Reconnaissance is the first step which includes a visit to the site and study of maps and other relevant records. It helps in deciding future programme of site investigations, scope of work, method of exploration to be adopted, types of samples to be taken and in-situ testing.

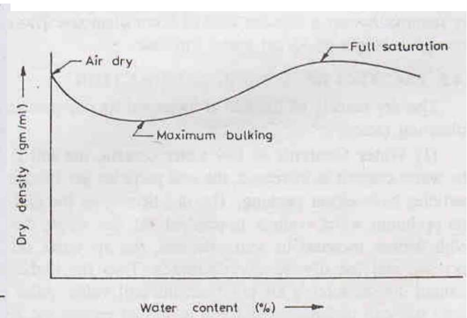
Preliminary exploration is to determine the depth, thickness, extent and composition of each soil stratum at the site. Depth of the bed rock and ground water table is also determined. Preliminary explorations are generally in the form of few borings or test pits. Tests are conducted with cone penetrometers and sounding rods to obtain information about strength and compressibility of soils.

Detailed explorations are done to determine the engineering properties of soils in different strata. It includes an extensive boring programme, sampling and testing of samples in laboratory. Fields tests are conducted in order to determine the soil properties in its natural state.</td><td>List – 1

2

2

2</td><td>7</td></tr>
<tr><td>IX</td><td>In the case of cohesive soils, the effect of water content on dry density of soil is well defined, and as water content increases the dry density also increases up to a maximum value termed as optimum moisture content, and after that dry density decreases with an increase in moisture content.




In the case of pure cohesionless soils, the effect of water content on dry density of soil is not well defined when the water content is below the optimum value. There is a large scattering of the points on the compaction curve. Generally, the dry density decreases with an increase in the water content in this range. This is due to bulking of sand. The maximum dry density occurs when the soil is fully saturated. If the water content is increased beyond this point, the dry density again decreases. They do not display a distinct optimum moisture content.</td><td>Figures – 4
Explanation - 3</td><td>7</td></tr>
<tr><td colspan="4">OR</td></tr>
<tr><td>X</td><td><table><tr><td>No</td><td>Compaction</td><td>Consolidation</td></tr><tr><td>1</td><td>Compaction is the compression of soil by the expulsion of air from the voids of the soil.</td><td>Consolidation is the compression of soil by the expulsion of water from voids of the soil.</td></tr><tr><td>2</td><td>It is a quick process.</td><td>It is a slow process.</td></tr></table></td><td>Any 7</td><td>7</td></tr>
</table>

3	Short term loading is required	Long term loading is required.
4	Loading is applied in a dynamic way.	Loading is static and constant.
5	Any type of soil either it is cohesion or Cohesionless can be compacted.	Consolidation applies to cohesive soils only especially for low permeable clay.
6	Degree of saturation of soil to be compacted should be less than 100%.	Degree of saturation of soil to be consolidated should be 100%.
7	Shear strength of soil increases.	Shear strength of soil increases.
8	Void ratio, compressibility and permeability decreases.	Void ratio, compressibility and permeability decreases.
9	Bearing capacity and settlement characteristics improve.	Bearing capacity and settlement characteristics improve.
10	Compaction is done purposely in order to get maximum dry density of soil.	Consolidation of soil occurs naturally due to structural loads from foundations.
11	It is done before the construction of structure.	It begins naturally along with the construction work.
12	To construct roads, earthen dams, embankments etc. compaction is useful.	The foundation soil properties will improve over long period due to consolidation.

XI	Consider a prism of gravel-sand soil 400 mm thick with a base area of $1 m^2$.		
	Volume, $V = 0.4\ m^3$		
	Volume of voids, $V_v = nV = 0.4 \times 0.4 = 0.16\ m^3$	3	
	Volume of water, $V_w = S\ V_v = 0.6 \times 0.16 = 0.096\ m^3$		
	$V_a = V_v - V_w = 0.16 - 0.096 = 0.064\ m^3$	3	7
	Water from rainfall has to fill this volume of air in order to saturate the soil. The required amount of rainfall is $\frac{0.064\ m^3}{1}$ = 64 mm	1	
	OR		
XII	The volume of solids in the finished volume of embankment, $$V_s = \frac{V}{1+e} = \frac{600000}{1+0.75} = 342857\ m^3$$	2	
	Volume of soil required to be taken out from borrow pit A, $V = V_s(1+e) = 342857(1+0.8) = 617143\ m^3$	2	
	Volume of soil required to be taken out from borrow pit B, $V = V_s(1+e) = 342857(1+1.7) = 925714\ m^3$		7
	Transportation cost if borrow pit A is used = 617143 X 10 = Rs. 6171430	2	
	Transportation cost if borrow pit B is used = 925714 X 5 = Rs. 4628570		
	Therefore, borrow pit B is more economical.	1	

XIII	The two types of boring that can be adopted in rocks are Percussion drilling and core drilling. **Percussion drilling** method is used for making holes in rocks, boulders and other hard strata. In this method a heavy chisel is alternately lifted and dropped in a vertical hole. The material gets pulverized. If the point where the chisel strikes is above the water table, water is added to the hole. The water forms a slurry with the pulverized material, which is removed by a sand pump or a bailer at intervals. The main advantage of using percussion drilling is that it can be used for all types of materials. One of the major disadvantages is that material at the bottom of the hole is disturbed by heavy blows of the chisel, so not possible to get good quality undisturbed samples. Also, the method is expensive than other methods. **Core drilling** method is used for drilling holes and for obtaining rock cores. In this method, a core barrel fitted with a drilling bit is fixed to a hollow drilling rod. As the drilling rod is rotated, the bit advances and cuts an annular hole around an intact core. The core is then removed form its bottom and is retained by a core lifter and brought to the surface. Water is pumped continuously to keep the drilling bit cool.	1 3 3	7
OR			
XIV	$\phi = 36^0$, hence general shear failure will occur. The ultimate bearing capacity of a strip footing in general shear failure is given by $q_u = CN_c + qN_q + 0.5B\gamma N_\gamma$ Since C=0, $q_u = qN_q + 0.5B\gamma N_\gamma$ $q = \gamma_d D_f = 17X1 = 17\ kN/m^2$ Ultimate bearing capacity, $q_u = (17X60) + (0.5X1.5X17X75) = 1976\ kN/m^2$	1 3 3	7

Question wise Analysis

Geotechnical Engineering – Model Question_2

Q. No	Module Outcome	Cognitive level	Marks	Time
I.1	MO 1.02	R	1	1
I.2	MO 1.02	R	1	1
I.3	MO 2.02	A	1	1
I.4	MO 2.03	R	1	1
I.5	MO 2.03	U	1	1
I.6	MO 3.01	R	1	1
I.7	MO 3.04	R	1	1
I.8	MO 4.03	R	1	1
I.9	MO 4.08	R	1	1
II.1	MO 1.04	R	3	10
II.2	MO2.01	R	3	10
II.3	MO 2.02	R	3	10
II.4	MO 2.03	U	3	10
II.5	MO 3.01	U	3	10
II.6	MO3.02	R	3	10
II.7	MO 3.04	R	3	10
II.8	MO 4.01	R	3	10
II.9	MO 4.01	R	3	10
II.10	MO 4.05	R	3	10
III.	MO 1.02	U	7	15
IV.	MO 1.04	A	7	15
V.	MO 2.02	U	7	15
VI.	MO 2.04	U	7	15
VII.	MO 4.06	U	7	15
VIII.	MO 4.01	U	7	15
IX.	MO 3.01	U	7	15
X	MO 3.05	U	7	15
XI.	MO 1.02	A	7	15
XII	MO 1.02	A	7	15
XIII	MO 4.03	A	7	15
XIV	MO 4.07	A	7	15

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Mark Distribution

Module	hr./module	Marks/Module $(h_i/\Sigma H_i)X123(\pm 5\%)$	Type of Questions							
			PART A		PART B		PART C		TOTAL	
			No. of questions	Marks	No. of questions	Marks	No. of questions	Marks	No. of questions	Marks
1	15	30	2	2	1	3	4	28	7	33
2	14	29	3	3	3	9	2	14	8	26
3	12	25	2	2	3	9	2	14	7	25
4	19	39	2	2	3	9	4	28	9	39
Total	60	123	9	9	10	30	12	84	31	123

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Cognitive Level Mark Distribution

Cognitive Level	Marks	% of marks
Remembering	31	25
Understanding	56	46
Applying	36	29
Analyzing	0	0
Evaluating	0	0
Creating	0	0
TOTAL	123	100