MADE EASY

India's Best Institute for IES, GATE & PSUs

Test Centres: Delhi, Noida, Hyderabad, Bhopal, Jaipur, Lucknow, Bhubaneswar, Indore, Pune, Kolkata, Patna

ESE-2021 : MAINS TEST SERIES

UPSC ENGINEERING SERVICES EXAMINATION

CIVIL ENGINEERING | Test No. 1

Geo-technical & Foundation Engineering [All Topics] + Environmental Engineering [All Topics]

Time Allowed : 3 hrs.

Maximum Marks: 300

Question Paper Specific Instructions

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

- Answers must be written only in **ENGLISH**.
- There are **EIGHT** questions divided in **TWO** sections.
- Candidate has to attempt **FIVE** questions in all.
- Question no. **1** and **5** are **compulsory** and out of the remaining **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. Diagrams/figures, wherever required, shall be drawn in the space provided for answering the question itself.
- Unless otherwise mentioned, symbols and notations carry their usual standard meanings. Attempt 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 Question-cum-Answer Booklet must be clearly struck off.

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE ASKED TO DO SO

Section A

Q.1 (a) **(i)** The void ratio and specific gravity of a sample of clay are 0.73 and 2.7 respectively. If the voids are 92% saturated, find the bulk density, the dry density and the water content. What would be the water content for complete saturation, the void ratio remaining the same?

(ii) Establish the following relationships:

1. $\gamma_d = (1 - n) \cdot G_s \gamma_w$
2. $\gamma' = \gamma_d + \gamma_w(n - 1)$

where, γ_d = dry unit weight of soil; γ' = submerged unit weight; γ_w = unit weight of water, G_s = specific gravity of solids; n = porosity.

[4 + 8 = 12 marks]

(b) Consider the following data of population for a city:

Year	1990	2000	2010	2020
Population	220800	345450	500910	678220

Calculate the following:

(i) Expected population of city in year 2030 as per geometrical increase method.

(ii) Expected population of city in year 2040 as per decremental decrease method.

(iii) Saturation population of city as per logistic curve method by considering $t_0 = 1990$

[12 marks]

(c) A total load of 900 kN is uniformly distributed over a rectangular footing of size 2 m × 3 m. Find the vertical stress at a depth of 2.5 m below the footing at a point, under one corner, and under the centre. If another footing of size 1 m × 3 m with a total load of 450 kN is constructed adjoining to the previous footing, what is the additional vertical stress at the point C, under one corner at the same depth due to construction of the second footing. Influence factor (I_N) for rectangular area is given below:

m	n	
	0.4	0.8
0.6	0.08	0.125
1.2	0.105	0.168

[12 marks]

(d) A 225 mm diameter sewer is designed to carry maximum sewage discharge of 0.004 m^3/s. If the velocity developed at full depth flow calculated as 0.8 m/sec. Then calculate the depth, velocity and slope at which the given sewer should be designed to carry given discharge. Use Manning's rugosity coefficient as 0.013.

d/D	0.20	0.30
q/Q	0.088	0.196

[12 marks]

(e) A new canal is excavated to a depth of 8 m below ground level, through a soil having the following characteristics:
c = 24 kN/m^2, ϕ = 25°, e = 0.8 and G_s = 2.70.
The slope of the banks is 1 in 1. Calculate the factor of safety with respect to cohesion when the canal runs full. If it is suddenly and completely emptied, what will be the factor of safety? Use the table below:

Taylor's stability number				
i \ ϕ	10°	15°	20°	25°
60°	0.138	0.116	0.097	0.079
45°	0.108	0.083	0.062	0.044
30°	0.075	0.046	0.0625	0.009

[12 marks]

Q.2 (a) **(i)** The observed cumulative drafts by a town are tabulated below, the drafts are at four hour interval.

Time	4 am	8 am	12 noon	4 pm	8 pm	12 mid-night
Cumulative draft (ML)	0.50	1.40	2.60	3.70	4.50	5.00

Calculate the equalizing storage for the above drafts when the pumping is done for 24 hours duration with constant rate.

(ii) Write short notes on the following

1. Detection of leakage by plotting hydraulic gradient line method.
2. Fire hydrants
3. Water meters

[14 + 6 = 20 marks]

(b) **(i)** In the laboratory, falling head test was conducted over a sample of fine grained soil and following data has been observed:

Diameter of the tube = 40 mm

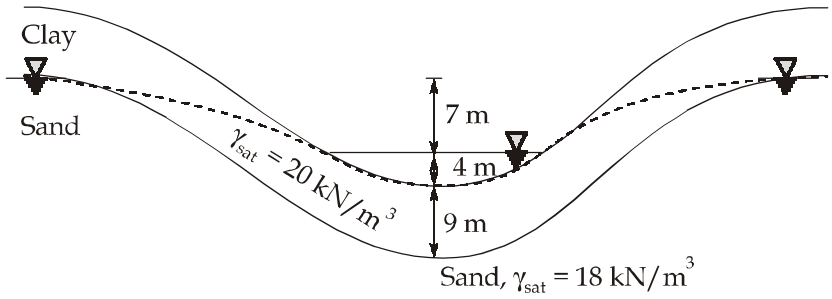
Diameter of the cell = 400 mm

Length of the soil sample = 2000 mm

The head of water at 30°C measured from the top level of the sample dropped from 1800 mm to 1600 mm within 1.5 hours. Calculate the coefficient of permeability of soil sample at 20°C.

Take dynamic viscosity of water at 20°C = 1.005×10^{-3} Ns/m^2 and at 30°C it is equal to $0.801 \times 10^{-3} \times$ Ns/m^2

(ii) Draw the total stress, pore water pressure and effective stress variation diagram for the soil profiles as shown in figure (γ_w = 10 kN/m^3, sand is under artesian pressure)



[10 + 10 = 20 marks]

(c) A sludge digestion tank is designed in waste water treatment plant for 15 MLD average flow of sewage carrying 215 mg/l concentration of organic suspended solid. It has been observed that out of all organic suspended solids 600 kg of nonvolatile solid and 30% of volatile solids digested. Calculate the diameter of sludge digestion tank required for carry out the digestion of sewage in 30 days. Assume

$G_{\text{Non-volatile solids}}$ = 2.45

$G_{\text{Volatile solids}}$ = 1.03

η_{PST} = 60%

Moisture content of raw sludge = 90%

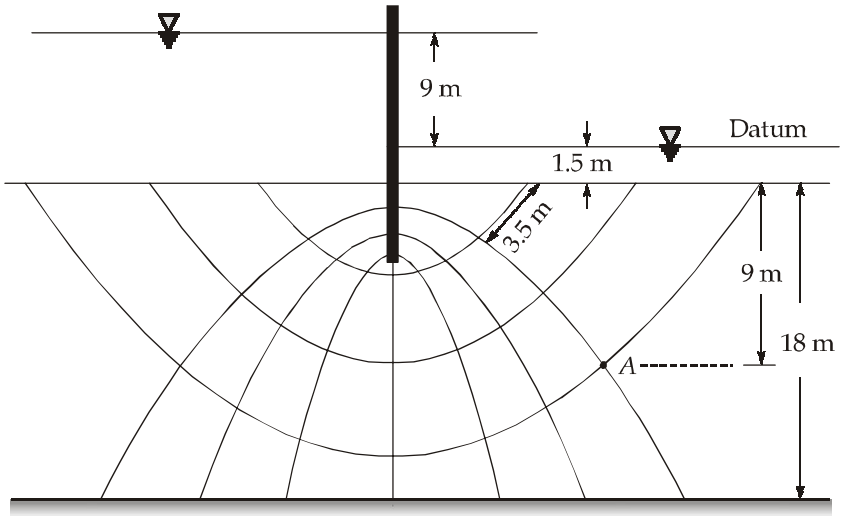
Moisture content of digested sludge = 80%

Depth of tank = 6 m

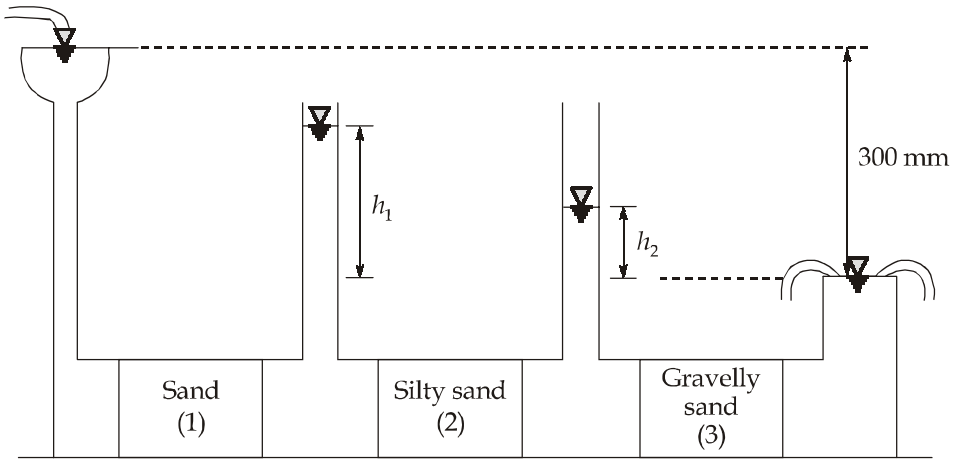
[20 marks]

Q.3 (a) **(i)** A sheet pile is driven into sandy silt and seepage takes place under the head difference of 9.0 m as shown in figure. The coefficient of permeability of the soil is 1.6×10^{-4} cm/sec and the water content of the soil is 33%. The specific gravity of the soil grains is 2.66. Using the flownet as shown in the figure, compute the following.

1. Flow rate in m^3/day per meter run
2. Pore water pressure at A.
3. Factor of safety against piping failure.



(ii) Three cylindrical granular soil samples of the same length and diameter are subjected to a constant flow as shown in the figure below. If the permeability of the sand, silty sand and gravelly sand are 2×10^{-2}, 6×10^{-3} and 4×10^{-2} cm/sec respectively, then determine the value of h_1 and h_2.



[10 + 10 = 20 marks]

(b) **(i)** Calculate the pH of mixture and normality of OH^- ions in a mixture obtained by mixing the following two solution A and solution B:
Solution A: Volume 200 ml and pH = 6
Solution B: Volume 1200 ml and pH = 8

(ii) A sample of X ml water taken for determination of alkalinity. The acid used as titrant has normality of N. The volume of acid used for titration upto end point of titration is V ml. Prove the expression for finding neutralize alkalinity during carbonate and bi-carbonate alkalinity in water can be $50000\left[\frac{NV}{X} - 10^{-pOH}\right]$ mg/l as $CaCO_3$.

[10 + 10 = 20 marks]

(c) **(i)** A soil profile at a certain location is as shown in figure below. A rigid circular foundation of 5 m diameter rests on sand. The contact pressure at the underside of the foundation is 250 kN/m^2. The average coefficient of compressibility of the clay is 0.606×10^{-3} m^2/kN. For the stress range encountered, estimate:

1. Ultimate settlement of clay layer
2. Compression index of clay

Assume

- Stress distribution to be at 2V : 1H with the vertical below ground level.
- Soil above water table to be dry.