1.1 Describe the processes responsible for the formation of soils from rock.

Solution 1.1

The main processes are physical and chemical weathering of rocks. Physical weathering involves reduction of size without any change in the original composition of the parent rock by processes such as exfoliation, unloading, erosion, freezing, and thawing. Chemical weathering causes both reductions in size and chemical alteration of the original parent rock. The main agents responsible for chemical weathering are hydration, carbonation, and oxidation. Often, chemical and physical weathering take place in concert.

1.2 (a) What is a mineral?
(b) Describe the differences among the three main soil minerals.
(c) Which mineral group is most important for soils and why?

Solution 1.2

(a) Minerals are crystalline materials and make up the solids constituent of a soil. Minerals are classified according to chemical composition and structure.

(b) Kaolinite has a structure that consists of one silica sheet and one alumina sheet bonded together into a layer about 0.72 nm thick and stacked repeatedly. The layers are held together by hydrogen bonds. Tightly stacked layers result from numerous hydrogen bonds. Illite consists of repeated layers of one alumina sheet sandwiched by two silicate sheets. The layers, each of thickness 0.96 nm, are held together by potassium ions. Montmorillonite (smectite) has a structure similar to illite, but the layers are held together by weak van der Waals forces. Sodium smectite can absorb enough water to cause the particles to fully separate. Calcium smectites do not usually absorb enough water to cause particle separation because of their divalent cations. Montmorillonite is often called a swelling or expansive clay.

(c) Silicates, because this group of minerals is abundant on earth.

1.3 Which of the three main clay minerals undergo large volume change in contact with water and why?

Solution 1.3

Montmorillonite. The layers in montmorillonite are bonded by van der Waals forces, which are very weak. Water can infiltrate the bond pushing the mineral layers apart.

1.4 (a) What is soil fabric?

(b) What is the name for the spaces between mineral particles?

(c) Why are the spaces between mineral particles important to geo-engineers?

(d) Explain the differences between a flocculated and a dispersed structure?

Solution 1.4

(a) Soil fabric refers to the structural arrangement of soil particles.
(b) Voids
(c) They contain liquids and gases, and control the settlement and strength of soils. If the voids space decreases the soil settles. The pressure of the water and gases in the voids affects the amount of stresses on the soil particles.
(d) A flocculated structure, formed in a freshwater environment, results when many particles tend to orient perpendicular to one another. A dispersed structure occurs when a majority of the particles orient parallel to one another.

1.5 Describe the differences among alluvial, collovial, glacial and lateritic soils.

Solution 1.5

Alluvial soils are fine sediments that have been eroded from rock and transported by water, and have settled on river and stream beds.

Collovial soils (collovium) are soils found at the base of mountains that have been eroded by the combination of water and gravity.

Glacial soils are mixed soils consisting of rock debris, sand, silt, clays, and boulders.

Lateritic soils are residual soils that are cemented with iron oxides and are found in tropical regions.

1.6 (a) What are the two types of surface forces in clayey soils.

(b) What is adsorbed water?

(c) Can you remove the adsorbed water by oven drying at 105° C? Explain.

Solution 1.6

(a) The surface forces on clay particles are London–van der Waals forces (attracting forces) and repelling forces from the diffuse double layer
(b) Adsorbed water is water that is bonded to the mineral surfaces.
(c) No, because it is bonded to the mineral surfaces.

1.7 What is the shape of the hole in a standard sieve?

Solution 1.7

Square.

1.8 What tests would you specify to determine the grain size of a sand that contains fine-grained soils?

Solution 1.8

A sieve analysis test followed by a hydrometer test on the particles less than 0.075 mm (passing the No. 200 sieve).

1.9 In a sieve analysis test, the amount of soil retained on all sieves 0.425 mm and above is 100 grams. The total mass used in the test is 500 grams,

(a) Determine the percentage of the soil greater than 0.425 mm (#40 sieve).
(b) Determine the percentage finer than 0.425 mm.

Solution 1.9

(a) the percentage of the soil greater than 0.425 = 100 x 100/500 = 20%
(b) the percentage finer = 100 - %retained = 100 -20 = 80%

1.10 The data from a particle size analysis on a sample of a dry soil at a depth of 0.5 m near a mountain range are given in the table below.

Sieve opening (mm)	9.53	4.75	2.0	0.84	0.425	0.15	0.074	Pan
Mass retained (grams)	0	31	38	58	126	120	68	58

(a) What is the total mass of the soil retained on all sieves including the pan?

(b) If the total mass used at the start of the test is 500 grams, what is the percentage loss? Explain why this loss occurred in the test.

(c) Plot the particle size distribution curve.

(d) What are the percentages of coarse-grained and fine-grained soils in the sample.

Solution 1.10

Initial mass	500 grams							
Sieve no.	3/8"	4	10	20	40	100	200	Pan
Opening (mm)	9.93	4.75	2	0.85	0.425	0.15	0.075	
Mass retained (grams)	0	31	38	58	126	120	68	58

A	B	C	D	E	F
Sieve no.	Opening (mm)	Mass retained (grams)	% retained (%)	S% retained (%)	% Finer (%)
		M_r	100 x M_r/M_t	S column D	100 - column E
3/8"	9.93	0	0.0	0.0	100.0
4	4.75	31	6.2	6.2	93.8
10	2	38	7.6	13.8	86.2
20	0.85	58	11.6	25.5	74.5
40	0.425	126	25.3	50.7	49.3
100	0.15	120	24.0	74.7	25.3
200	0.075	68	13.6	88.4	11.6
Pan		58	11.6		
	SUM	499	100.0		

(a) M_t = 499 grams

(b) Loss = 500 - 499 = 1 grams

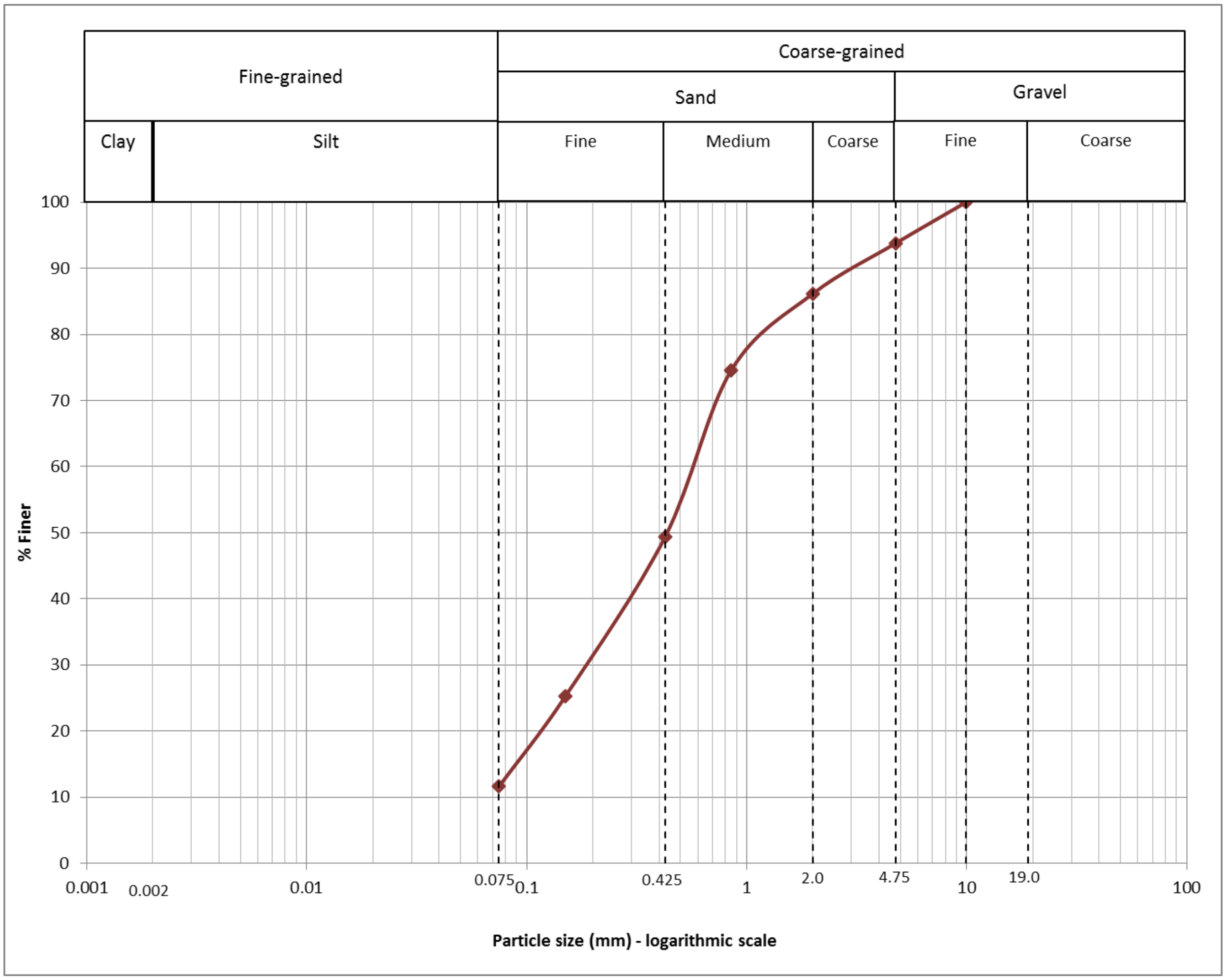
% loss = 1 /500 x 100 = 0.2

This loss usually occurs from soil sticking in the holes of the sieves.

(c) See figure below for particle size distribution plot

(d) % coarse-grained soil = 88.4

% fine-grained soil = 11.6



Fine-grained
Coarse-grained
Sand
Gravel
Clay
Silt
Fine
Medium
Coarse
Fine
Coarse
100
90
80
70
60
50
40
30
20
10
0
% Finer
0.001
0.002
0.01
0.075
0.1
0.425
1
2.0
4.75
10
19.0
100
Particle size (mm) - logarithmic scale

1.11 The effective depth measured in a hydrometer test after 8 minutes is 1 cm. (a) Determine the average particle size if K is 0.01341, and (b) Identify the soil type (e.g. silt or clay) corresponding to the average particle size.

Solution 1.11

$$D = K\sqrt{\frac{z}{t_D}} = 0.01341\sqrt{\frac{1}{8}} = 0.0047 \text{ mm}$$

Using the USCS classification, this soil is a silt (0.075 mm to 0.002 mm).

1.12 The following results were obtained from sieve analyses of two soils.

Sieve opening (mm)	Mass (grams) Soil A	Soil B
4.75	0	0
2.00	20.2	48.1
0.85	25.7	219.5
0.425	60.4	67.3
0.15	98.1	137.2
0.075	127.2	22.1
	168.2	5.6

Hydrometer tests on these soils gave the following results.

	% Finer	
Particle size (mm)	Soil A	Soil B
0.05	22.6	1
0.01	13.8	0.9
0.005	12.2	0.8
0.002	5	0.5

(a) Plot the gradation curve for each soil on the same graph.
(b) How much coarse-grained and fine-grained soils are in each soil?
(c) What are the percentages of clay and silt in each soil according to USCS?
(d) Determine D_{10} for each soil.
(e) Determine the uniformity coefficient and the coefficient of concavity for each soil.
(f) Describe the gradation curve (e.g. well graded) for each soil?

Solution 1.12

(a to e)

Soil A

A	B	C	D	E	F
Sieve no.	Opening (mm)	Weight retained (gm)	% retained (%)	Σ% retained (%)	% Finer (%)
		M_r	100 x M_r/M_t	Σ column D	100 - column E
3/8"	9.93	0	0.0	0.0	100.0
4	4.75	0	0.0	0.0	100.0
10	2	20.2	4.0	4.0	96.0
20	0.85	25.7	5.1	9.2	90.8
40	0.425	60.4	12.1	21.3	78.7
100	0.15	98.1	19.6	40.9	59.1
200	0.075	127.2	25.5	66.3	33.7
Pan		168.2	33.7		
	SUM	499.800	100.0		

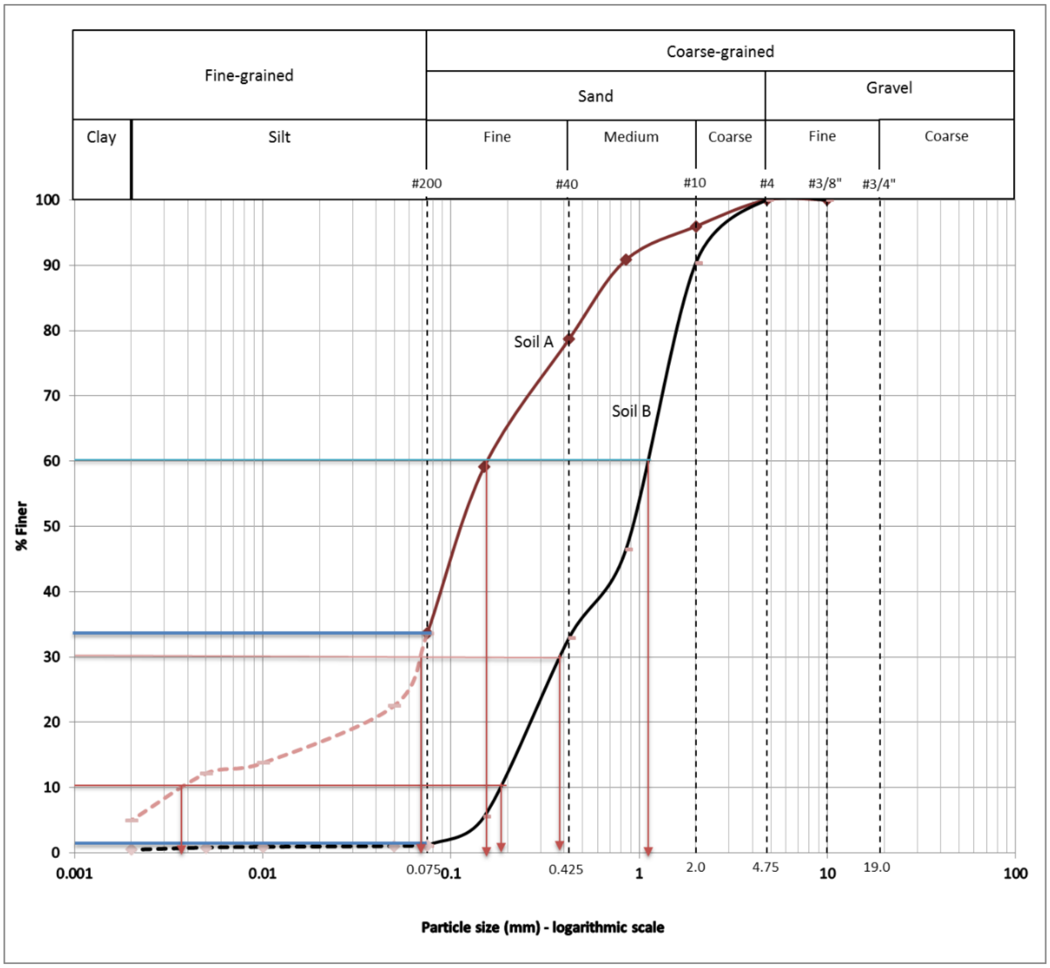
Gravel (%)	0.0
Sand (%)	66.3
Silt + Clay (%)	33.7
D_{60}	0.16
D_{10}	0.0038
D_{30}	0.007
C_u	42.1
C_c	0.081

Soil B

A	B	C	D	E	F
Sieve no.	Opening (mm)	Weight retained (gm)	% retained (%)	Σ% retained (%)	% Finer (%)
		M_r	100 x M_r/M_t	Σ column D	100 - column E
3/8"	9.93	0	0.0	0.0	100.0
4	4.75	0	0.0	0.0	100.0
10	2	48.1	9.6	9.6	90.4
20	0.85	219.5	43.9	53.5	46.5
40	0.425	67.3	13.5	67.0	33.0
100	0.15	137.2	27.5	94.5	5.5
200	0.075	22.1	4.4	98.9	1.1
Pan		5.6	1.1		
	SUM	499.800	100.0		

Gravel (%)	0.0
Sand (%)	98.9
Silt + Clay (%)	1.1
D_{60}	1.1
D_{10}	0.18
D_{30}	0.38
C_u	6.1
C_c	0.73

Particle size (mm)	Soil A	Soil B
0.075	33.7	1.1
0.05	22.6	1
0.01	13.8	0.9
0.005	12.2	0.8
0.002	5	0.5



Soil A: Clay: (clay + silt + 33.7%); ; 5 % <0.002 mm; Clay = 5%, 28.7% silt

Soil B: Clay: (clay + silt = 1.1%); 0.5 % <0.002 mm; Clay = 0.5%, Silt = 0.6% silt

f) Both soils can be described as well-graded based on C_u (≥ 4 (gravel), ≥ 6 (sand)-> well graded) and C_c (Range 1 to 3 -> well graded).

1.13 Why do geo-engineers plot particle distribution curves on a semi-log scale with particle size on the abscissa (logarithmic scale) versus % finer on the ordinate (arithmetic scale)? Is there any theoretical justification for this? Would the shape of the grain size graph be different if arithmetic rather than semi-log scale is used?

Solution 1.13

The semi-log plot is used for convenience because the particle size distribution in natural soils can be very large. There is no theoretical justification. Yes, the shape of the grain size graph will be different because the log scale tends to squeeze the particle size distribution laterally.

1.14 If a soil consists of sand and fines, would drying the soil and then sieving it through a standard stack of sieves give accurate results on the fines content? Justify your answer.

Solution 1.14

No. The fines will cluster together or adhere to the sand.

1.15 If you have to select a soil for a roadway that requires good drainage qualities, what type of soil would you select and why?

Solution 1.15

A coarse-grained soil such as sand or gravel because coarse-grained soils generally have higher bearing (load) capacity, lower settlement, and better drainage than fine-grained soils.

1.16 A house foundation consists of a concrete slab casted on a clay soil. The homeowner planted vegetation near one side of the foundation and watered it regularly, sometimes excessively. She noticed that this side of the foundation curled upwards, the concrete slab cracked and several cracks appeared on the wall. What do you think is likely the predominant mineral in the clay soil? Justify your answer.

Solution 1.16

Montmorillonite. This clay mineral expands in contact with water. The expansion will push the edges of the slab upwards causing the concrete slab to crack.