Indiana Registry of Soil Scientists
Performance Objectives for the Soil Science Fundamentals Exam

You should be able to do the tasks indicated by the verbs in bold type in the objectives listed below by topic.

SOIL DIFFERENCES

1. **Use** the Munsell system to **describe** soil color and **explain** the Munsell code including the concepts of hue, value, and chroma.
2. **Name** and **explain** the origin of the colors in soil which are caused by iron, by organic matter, and the colors observed in the absence of iron and organic matter.
3. **Discuss** how and why surface and subsoil soil colors change as one goes from well drained to poorly drained soil.
4. **List** the particle size limits for sand, silt, and clay.
5. Given an unlabeled textural triangle, **explain** its general organization and **label** the 12 textural classes.
6. Given a sample of soil, **determine** its texture by feel, placing it in its correct textural class.
7. **Define** "texture" and "structure".
8. **Define** "ped", and discuss how peds are formed.
9. **Identify** and **describe** the two "structureless" conditions in soil: single grained and massive.
10. **Identify** and **describe** granular, platy, blocky, and prismatic soil structures.

PHYSICAL PROPERTIES OF SOILS

1. **Name** and **write** the chemical formula for the oxidation states of iron in soil and identify the soil colors associated with each oxidation state.
2. **Recognize** whether a soil is well drained, poorly drained or somewhere in between (moderately well or somewhat poorly) and **explain** why and how this is indicated by color.
3. **Explain** the influence of texture on other physical properties and on soil management.
4. **List** and **explain** the four steps in preparing a soil for texture analysis by the sedimentation hydrometer method.

5. Given Stokes Law, **explain** each factor in it and how each factor affects the settling velocity of particles (covered in lecture). **Explain** which variables are assumed to be constant and which ones are variable and thus influence the texture determination.
6. Given either, the percent sand, silt, and clay, or the hydrometer readings for a soil taken at 40 seconds and 2 hours, be able to **use** the textural triangle to determine textural class.
7. **Describe** the importance of soil temperature and what management practices are useful in manipulating soil temperatures. Be able to **list** some soil properties that influence soil temperature.
8. **Determine** bulk density and **explain** the relationship it has to pore space and why it is an important soil property.
9. **Calculate** percent pore space when bulk density and particle density are given.
10. **Assess** the importance of macro and micro pores in water retention and soil aeration and **list** three effects of poor aeration.

SOIL FORMATION

2. **Understand TIME** as a factor in soil formation. Be able to list the changes that usually take place in soil as it ages.
3. **Describe** how **CLIMATE** (temperature and precipitation) affects the (a) humus content and depth, (b) depth of weathering, (c) presence of an argillic (clay) horizon, and (d) exchangeable cation (Ca^{++}, Mg^{++}, K^{+}) composition of soils.
4. Be able to (a) **Explain** what nutrient recycling by the plants does to a soil during soil formation; (b) **explain** how marsh grass, prairie grass, deciduous trees and coniferous trees as vegetation types each produce a different soil; and (c) **identify** the most probable **NATIVE VEGETATION** by looking at the soil.
5. **Assess** the effect of **TOPOGRAPHY** (slope and drainage) on soil development. Given a description or sketch of a landscape be able to **predict** where well drained and poorly drained soils will occur and where the deepest and darkest soils will occur.
6. **Define** the term **CATENA** as used in soils.
7. **Distinguish** the soil drainage classes (well, moderately well, somewhat poor and poorly drained soils) from the colors in the soil profile.
8. **Identify** and **describe** the residual **PARENT MATERIALS** common to Indiana and to locate the areas on a map.
9. **Identify** and **explain** the differences between glacial till and glacial outwash and to locate the areas of Wisconsin and Illinoian glacial **PARENT MATERIALS** on an Indiana map.

10. **Define** and **identify** loess and **explain** its mode of deposition and its areas of prevalence as a **PARENT MATERIAL** in Indiana.
11. **Review** pedon descriptions and **learn** the system of horizon designations.

SOIL CLASSIFICATION

1. **Employ** the system of "Rectangular Survey to:

   a) **describe** land locations and acreages.

   b) **locate** the land areas on soil survey or topographic maps when given the legal land description.

3. **List** two advantages in having a workable system for classifying soils.
4. **Discuss** the criteria used and the purpose for classifying soils in Soil Taxonomy.
5. **List** the six categories (levels) of classification in Soil Taxonomy, the US system of soil classification, and put them in order.
6. Given the classification of a soil (e.g., Mollic Haplaqualfs), **identify** the Soil Order, Suborder, Great Group and Subgroup names.
7. **Name** the 12 orders and some distinguishing features of each.
8. **Organize** the following five soil orders into the most probable order of increasing development: Entisol, Inceptisol, Alfisol, Ultisol, and Oxisol.
9. **Describe** 4 surface and 5 subsurface diagnostic horizons.
10. **Explain** criteria used and purpose for classifying soils in the Land Capability Class System.

EROSION AND WATER QUALITY

1. **Discuss** the problems associated with soil erosion in: (1) agriculture, (2) urban development, and (3) recreation sites and especially to explain the general environmental concerns in all cases.
2. **Describe** the two mechanisms (detachment and transport) recognized in accelerated erosion by water and wind.
3. **Define** the universal soil loss equation (USLE) and **explain** what each symbol represents.
5. **Explain** what determines the magnitude of the T value, rainfall factor, R and the soil erodibility factor, K.
6. **Describe** how length of slope and steepness of slope is related to the amount of soil erosion by water.
7. **Explain** the reasons for tilling the soil.

8. **Describe** four tillage systems commonly used in Indiana.
9. **Explain** how each tillage system affects the amount of erosion occurring (i.e., the size of the cropping management factor, C).
10. **List** three common conservation practices used to reduce the conservation practices factor, P, and explain how each is effective in reducing erosion and how effective it is.
11. **Recall** the approximate magnitude of the values of R, K, LS, C, P, and T for Indiana conditions on tilled land.

WATER IN SOILS

1. **Explain** the polarity and hydrogen bonding properties of water.
2. **Explain** why we have cohesive and adhesive forces in soil-water systems and what adhesion water and cohesion water is.
3. **Discuss** the concept of soil water potential and its various components of "suction" and "tension" and the method of expressing their magnitudes in units of bars and/or kilopascals (kPa). Also **explain** the difference between the "amount" of soil moisture and "how tightly it is held" in the soil.
4. **Calculate** % moisture by weight and by volume.
5. **Explain** how to measure the amount of soil water gravimetrically, by neutron scattering (with the neutron probe), with water potentiometers (tensiometers), by time-domain reflectrometry (TDR), and by electrical conductivity.
6. **Define** saturated (gravitational) and unsaturated (capillary) flow of water in soils.
7. **Use** the concepts of water content at "saturation", "field capacity", and the "permanent wilting point" and **know** how they are related to plant-"available" and "unavailable" water. Calculate "available" water in soils.
8. **Recall** the approximate amount of rain water a sandy loam and a clay loam soil can store as available water (in cm/meter of inches/foot).
9. **Describe** capillary rise of water from a water table and how it differs for sand, silt and clay.
10. **Explain** with a sketch, the functioning of the Prescription Athletic Turf (P.A.T.) system.
11. **Discuss** the fate of rain water (evaporation, transpiration, runoff and percolation).
12. **Discuss** the effects of mulches on water intake (infiltration) and water loss.
13. **Explain** how fallowing accumulates water in dry region soils.
14. **Describe** the kinds of soils best suited for irrigation and **discuss** several of the practices important for making irrigation profitable.
15. **Describe** the various surface, subsurface, sprinkler and drip methods for applying irrigation water.

16. **Explain** how systems of surface drainage and tile drainage work, and be able to discuss at least 3 benefits from improved drainage.

SOIL COLLOIDS AND CATION EXCHANGE CAPACITY

1. **List** the two types of soil colloids which are responsible for the negative charge exhibited by soils.
2. **Define** cation exchange capacity and write the units used in expressing it.
3. **Explain** what we mean by a mole and a centimole of charge, and be able to calculate the centimole weight for simple ions, complex ions, and compounds.
4. **Identify** the origin of the negative charge on clay minerals; both that resulting from exposed crystal edges and that from isomorphic substitution.
5. **Diagram** and **label** the various structural features of the following clay minerals:
   a) Kaolinite (1:1, nonexpanding)
   b) Hydrous Mica (Illite, 2:1, nonexpanding)
   c) Montmorillonite (2:1, expanding)
6. **Compare** and **contrast** how each of the clay minerals affect the soil properties of water holding capacity, shrink-swell, nutrient holding capacity.
7. **List** two sources of negative charge on soil humus.
8. **Recall** the approximate cation exchange capacity (CEC) for humus, montmorillonite, illite, and kaolinite.
9. **Calculate** the cation exchange capacity (CEC) and the % base saturation (% B.S.) of a soil, given the quantity of cations distributed on the soil exchange sites.
10. **Calculate** approximate values for the CEC of mineral and organic soils, given the clay and humus content.
11. **Assess** the relative importance of cation exchange for fertilizer and lime retention, and waste product purification.
12. **Explain** how K^+, Na^+, Mg^{++}, Ca^{++}, H^+ and Al^{+++} compete for cation exchange sites on soil colloids.

SOIL pH and LIMING

1. **Explain** the concept of "pH". When given the pH, be able to calculate H^+ concentration in terms of molarity (M) and vice versa.
2. **Explain** why soils are acid or alkaline. Be able to show by chemical equations how H^+, Al^{+++}, Ca^{++} and Na^+ in conjunction with soil particles and water produce alkalinity or acidity.

3. **Differentiate** between "reserve" (i.e. associated) and "active" (i.e. dissociated) acidity.
4. **Describe** how soils "buffer" the effect of liming on acidification.
5. **Describe** the relationship that exists between pH and percent base saturation and diagram this relationship for a typical soil.
6. **Explain** how soil pH is measured by indicator dyes and by the glass electrode pH meter and give a brief explanation of the technique used in each..
8. **Calculate**, given the centimoles of acid per kg soil, the amount of $CaCO_3$ needed per kg soil (and per acre or hectare) to neutralize it.
9. **Explain** how soils become acid from weathering and cropping.
10. **Explain** why pH affects crop growth and assess the effect of pH on the
    a. solubility of aluminum, iron and manganese and similar metal ions
    b. availability of calcium and magnesium
    c. availability of phosphate and molybdate
    d. activity of soil microorganisms
11. **List** the materials used to acidify a soil and describe how they work.
12. **List** which of the compounds (CaO, $Ca(OH)_2$, $CaCO_3$, $CaCl_2$, $CaSO_4$, $MgCO_3$, Mar1) are good liming materials and **explain** why each is or is not a good liming material.
13. **Explain** the importance of each of the following in determining the quality of a liming material.
    a) its neutralizing value (calcium carbonate equivalent)
    b) its Ca and Mg content
    c) its fineness

ORGANISMS OF THE SOIL

1. **Name** several types of soil animals, give a brief description, and explain their importance.
2. **Describe** the methods used for extracting animals from the soil (e.g. Berlese funnel and the nematode extracting system).
3. **Explain** how we measure microorganism activity by CO_2 evolution and the serial dilution plating techniques.
4. **Name** a parasitic or pathogenic soil organism and **describe** how it causes plant disease or injury.
5. **Describe** mycorrhizae and **explain** their importance to higher plants.
6. **Diagram** the nitrogen cycle including its pathways and the soil organism involved.

7. **Differentiate** between aerobic, anaerobic, autotrophic (chemolithotrophs), and heterotrophic (chemoorganotrophs).
8. **Explain** symbiotic and nonsymbiotic N fixation and its importance to both cultivated and natural ecosystems.
9. **Name** the soil bacteria responsible for N fixation and nitrification, and be able to **describe** the conditions that favor each.
10. **Explain** why one would use a nitrification inhibitor and how a commonly used one functions.
11. **Describe** the influence of pesticides and fertilizers on soil organisms.
12. **Explain** how one sterilizes soil, the effects of soil sterilization, and when it is used.
13. **Discuss** bioremediation and how it can be used to cleanup environments contaminated with hazardous organic waste.

ORGANIC SOILS AND ORGANIC MATTER

1. **Explain** how muck and peat soils develop.
2. **List** the criteria which distinguishes a mineral soil from an organic soil.
3. **Distinguish** between a peat and a muck soil.
4. **List** the characteristics of sedimentary, fibrous and woody peats.
5. **List** two commercial uses of peats and mucks.
6. **List** and **explain** the soil order and suborder classification for organic soils.
7. **List** at least five management problems which occur with organic soils.
8. **List** and **explain** four economic factors which must be considered before starting to farm organic soils.
9. **Explain** the effects of native vegetation and drainage on organic matter accumulation.
10. **Know** the approximate C:N ratio of soil humus, soil organisms, and common residues, such as alfalfa, manure, corn stalks, wheat straw, and sawdust.
11. **Explain** how the addition of residues with different C:N ratios affects decomposition rate and N availability as related to mineralization and immobilization.
12. **List** and **explain** ways to compensate for wide C:N ratios in residues and avoid N deficiencies.
13. **Explain** the importance of organic matter to the physical and chemical properties of soils.

PLANT AND SOIL ANALYSIS

1. **List** (correctly spelled) from memory all of the 18 elements essential for plants and classify each as a macronutrient (primary or secondary) or micronutrient.
2. Given an essential element, **write** the ionic or molecular forms of it which are taken up by plants.
3. **List** the three steps in plant and soil analysis: sampling, analysis, interpretation.
4. **Describe** in detail how to sample a field for **plant** analysis including sample taking, preparation and submission. **Discuss** good **soil** sampling procedures including number of sub-samples, size and type of area to sample, depth of sample, and sources of error in sampling.
5. **Identify** what plant part and at what growth stage one should sample tomatoes, corn and oak for plant analysis.
6. **Explain** how actual plant analysis is done in a certified lab including what analyses are made.
7. Given any one of the elements commonly reported in plant analysis, **recall** whether the sufficiency level is more appropriately reported in percent or in ppm.
8. Given values from plant analysis for N, P, or K, be able to **select** the values falling within the "sufficiency" range.
9. **Explain** "Phosphorus Fixation".
10. **Explain** "Potassium Fixation".
11. **Explain** why a soil nitrogen test is usually not run and how N needs are determined.
12. **List** the tests run in a "routine" or "basic" soil test.
13. **Explain** how a soil test lab obtains a soil's cation exchange capacity, and be able to do the calculations when given the appropriate data.

FERTILIZERS

1. **Discuss** animal and municipal wastes: a) as fertilizers; b) from an economic standpoint; and c) from an environmental standpoint.
2. **Describe** the basic processes for manufacturing ammonia, ammonium nitrate, urea, diammonium phosphates, and nitrogen solutions.
3. **Recall** the chemical composition and percent nitrogen of anhydrous ammonia, ammonium nitrate, urea, 28% N solutions and diammonium phosphate.
4. **Discuss** the advantages and disadvantages of the gas, liquid, and solid forms of N fertilizer as affected by cost, analysis, and handling ease.
5. **Explain** how slow release fertilizers are made from urea and the special uses for them.

6. **Explain** the process used to produce the three kinds of phosphorus fertilizers (rock phosphate, concentrated super phosphate, and ammonium phosphates) and their chemical composition and % P_2O_5.
7. **Discuss** the advantages and disadvantages of the three forms of phosphate fertilizer as affected by cost and solubility.
8. **Explain** the process used to produce the two common kinds of potassium fertilizers and the chemical composition and % K_2O of each.
9. **Discuss** the advantages and disadvantages of two forms of potassium fertilizers as affected by cost and crop species.
10. **Explain** the differences between blended and granular fertilizers and between solution and suspension fertilizers.
11. **Explain** what a fertilizer label means.
12. **Explain** how the fertilizer control law provides for inspection and enforcement of fertilizer quality.
13. **Calculate** the conversion factor and convert % P or K to % P_2O_5 or K_2O or the reverse.

FERTILIZER PRACTICES

1. **Diagram**, **label**, and **discuss** a graph illustrating typical response of crop yield to added fertilizer.
2. **List** and **explain** the factors that determine the amount of fertilizer needed.
3. **Explain** the influence of relative mobility of N, P, and K in soil on fertilizer placement and timing.
4. **Discuss** reasons for selecting preplanting, at planting, or postplanting as a time for fertilizer application.
5. **Explain** and **demonstrate** how fertilizer recommendations are made.
6. **Explain** the differences between broadcast and other methods of fertilizer application and the advantages and of each method.
7. **Explain** the effects of fertilizers on soil pH.
8. **Explain** the concept of "diminishing returns". Show the difference in point of maximum yield and point of maximum profit per acre.

SOILS AND CHEMICAL POLLUTION

1. **Describe** toxic chemicals focusing on the environmental damage caused by these organic compounds.

2. **Differentiate** the various classes of pesticides, insecticides, fungicides, herbicides, and nematicides.
3. **Explain** the behavior of organic chemicals in soil, give a brief description of volatility sorption, leaching, contamination of groundwater, chemical reactions, microbial metabolism, plant adsorption, and persistence in soil.
4. **Understand** the effects of pesticides on soil organisms.
5. **Explain** the key parameters affecting movements of pesticides through soil 1) Half life for biodegradation of the pesticide and 2) The partition coefficient (written as Kd and Koc).
6. **Describe** how Kd and Koc differ.
7. **Describe** the factors affecting biodegradation: photodegradation, hydrolysis, and microbial degradation.
8. **Explain** pesticide movement into tile drains.
9. **Explain** why nitrates move in soil and can potentially contaminate groundwater.
10. **Describe** bioaccumulation/bioconcentration.
11. **Discuss** land application of sewage sludge and the potential buildup of heavy metals.