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問題用紙 **専門科目** [**一般選抜**]

Question Sheet Specialized Subject General Selection

問1 図1のような不かく乱土壌カラム (長さ L : 60 cm、直径 5 cm) を用いて水の飽和浸透実験を行った。次の問いに答えよ。

- (1) 実験①では、流入側および流出側のマノメーターの水位がそれぞれ基準面から $h_1=60$ cm、 $h_2=30$ cm であり、その時の流出量 (Q) は $1 \text{ cm}^3 \text{ sec}^{-1}$ であった。不かく乱土壌の飽和透水係数 (cm sec^{-1}) を求めよ。
- (2) 実験①において、流入側からトレーサー (高濃度の Cl^-) を流す実験も同時に行った。その結果、その流出口へのトレーサーの到達時間は 600 sec であった。この場合の土壌カラムの間隙率を求めよ。
- (3) 実験②では、流入量を実験①の 25% に減少させた。その場合のマノメーターの水位差を求めよ。
- (4) ダルシー則について、式を示せ。
- (5) また、その限界についても説明せよ。

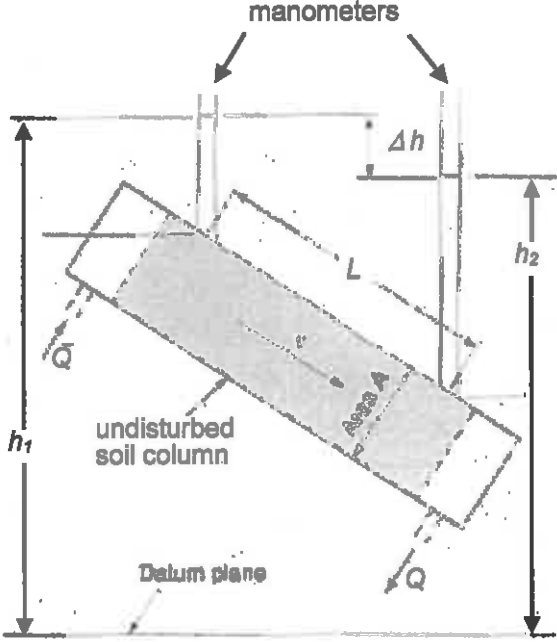


図1 不かく乱土壌を用いたカラム実験の模式図

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Question 1 Figure 1 shows the schematic diagram of water flow experiment, using an undisturbed soil column with 60 cm long (L) and 5 cm in diameter. Based on these situations, answer the following questions.

(1) In Experiment ①, water levels at the manometers on the sides of inlet and outlet were 60 cm (h_1) and 30 cm (h_2), respectively from datum plane and inflow rate was $1 \text{ cm}^3 \text{ sec}^{-1}$. Estimate the hydraulic conductivity (cm sec^{-1}) of the undisturbed soil column in the experiment.

(2) In Experiment ①, a tracer (high content of Cl^-) was also injected from the inlet. Its arrival time at the outlet was 600 seconds after the injection. Estimate the porosity of the undisturbed soil sample in this case.

(3) In Experiment ②, inflow rate was reduced to 25% of that in Experiment ①. Estimate the water level difference between the manometers.

(4) Describe Darcy's equation.

(5) Explain the limitation of this equation.

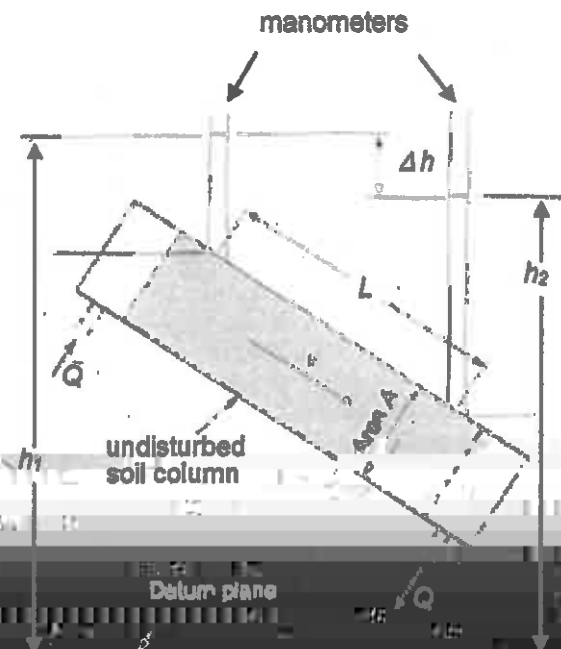


Figure 1 Schematic diagram of the column experiment using an undisturbed soil sample.

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問2 流域スケールの水収支について、次の問いに答えよ。

- (1) ある流域における降水量(P)、蒸発散量(ET)、河川流出量(Q_r)、地下水流出量(Q_g)、貯留量変化(Δ)を考慮した水収支式を示せ。特に、地下水流出量および貯留量変化の取り扱いについて、説明せよ。
- (2) 日本の流域と大陸の流域を比較して、地下水流出量の違いについて説明せよ。
- (3) 年間水収支で、降水量が 1500 mm の年は河川流出量が 800 mm であったが、2000 mm の年には 1500 mm になった。この場合の蒸発散量の変化とその理由を説明せよ。

(4) 流域の土地利用が長期的に変化した。具体的には、森林から住宅地への変化(都市化)が目立った。この場合の水収支式における項目の変化を説明せよ。

(5) 流域内の森林試験地において、詳細な水文過程の季節変化を観測した(図2 a,b)。この間にどのような変化があったか、またその理由を具体的に説明せよ。

*1: Staelens, J, Herbst, M, Hölscher, D., and Schrijver, A.D (2011) Seasonality of Hydrological and Biogeochemical Fluxes, in "Forest Hydrology and Biogeochemistry" eds. by Levia et al., 521-539, Springer.

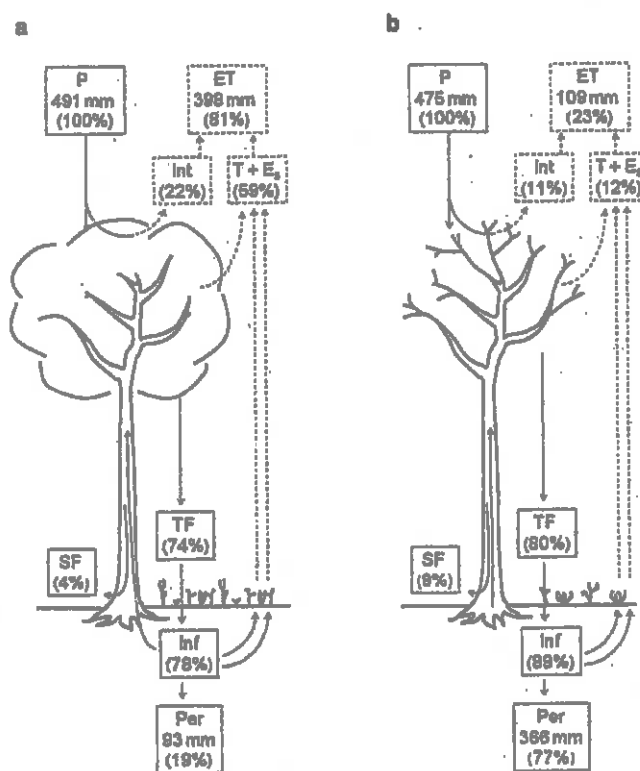


図2 ある流域内の森林域における水収支の季節変化 (a, b) の観測結果 (Staelens et al. 2011^{*1} 一部改変)

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Question 2 Answer the following questions about the water balance in a catchment scale.

(1) Describe the water balance equation including the terms of precipitation (P), evapotranspiration (ET), river discharge (Q_r), groundwater discharge (Q_g) and change in storage (Δ) in a catchment. Add some comments on groundwater discharge and change in storage.

(2) With comparing the Japanese and continental catchments, explain the difference of groundwater discharge.

(3) Based on the annual water balance, river discharge (Q_r) was 800 mm when the precipitation (P) was 1500 mm, however, Q_r was 1500 mm when the P was 2000 mm. Explain the change in evapotranspiration (ET) and the reason for that.

(4) Land use in the catchment has been changed on

long-term basis and specifically from forest to

(5) The detailed seasonal changes in hydrological

processes were observed on the forest site in the catchment (Figure 2a, b). Explain the characteristics of the changes and the reason for that between the two seasons.

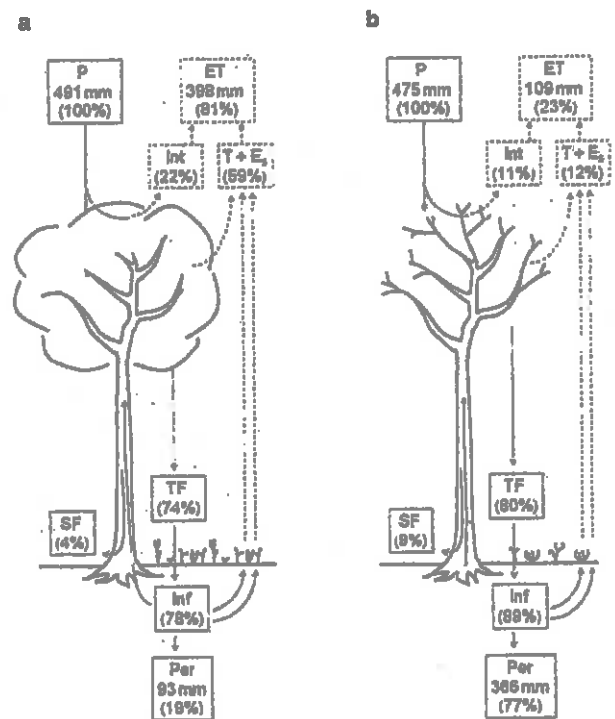


Figure 2 Observed seasonal change of water balance in the same forest area (a, b) of the catchment. (modified Staelens et al.2011*)

*1: Staelens, J, Herbst, M, Hölscher, D., and Schrijver, A.D. (2011) Seasonality of Hydrological and Biogeochemical Fluxes, in "Forest Hydrology and Biogeochemistry" eds. by Levia et al., 521-539, Springer.

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問題1 (Question 1)

領域 $D = \{x^2 + y^2 \leq 1\}$ 上の2重積分,

$$I = \iint_D \frac{\ln(x^2 + y^2)}{\sqrt{x^2 + y^2}} dx dy$$

について, 以下の問いに答えよ。

- (a) 積分領域を x - y 平面図に示し, その領域にハッチングをつけ, かつ x , y 軸上の数値を記入せよ。
- (b) $(x, y) = (r \cos \theta, r \sin \theta)$ の変数変換を行う際のヤコビアン行列式を求めよ。なお, $(x, y) \rightarrow (r, \theta)$ の変数変換におけるヤコビアン行列式 J は, 以下の通り与えられる。

$$J = \begin{vmatrix} \frac{\partial x}{\partial r} & \frac{\partial x}{\partial \theta} \\ \frac{\partial y}{\partial r} & \frac{\partial y}{\partial \theta} \end{vmatrix}$$

- (c) 2重積分 I を求めよ。

Answer the following questions about the double integral I on the region $D = \{x^2 + y^2 \leq 1\}$.

$$I = \iint_D \frac{\ln(x^2 + y^2)}{\sqrt{x^2 + y^2}} dx dy$$

- (a) Show and hatch the domain of the integral at the x - y plane and express numerical values on the x and y axes.
- (b) Convert the variables with $(x, y) = (r \cos \theta, r \sin \theta)$, then calculate the Jacobian determinant, J . Note that the Jacobian determinant can be written by the following formula for the coordinate transformation, $(x, y) \rightarrow (r, \theta)$.

$$J = \begin{vmatrix} \frac{\partial x}{\partial r} & \frac{\partial x}{\partial \theta} \\ \frac{\partial y}{\partial r} & \frac{\partial y}{\partial \theta} \end{vmatrix}$$

- (c) Calculate the double integral I .

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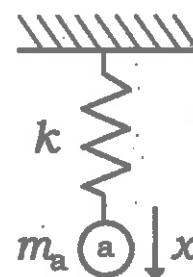
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問題 2 (Question 2)

図のように、物体 a (質量: m_a) がばね定数 k の軽いばねに繋がれている。運動はばねの方向に束縛されているとした場合について以下の問いに答えよ。なお、重力加速度を g 、時間を t とし、図の向きに x 軸をとり、ばねの自然長での物体 a の位置を原点とする。

- (a) つり合いの位置 x_a を求めよ。
- (b) x_a の位置を中心に物体 a が単振動する時の運動方程式、及び一般解 $x(t)$ を求めよ。
- (c) 初期条件 $x(0) = x_0$, $x'(0) = v_0$ を満たす解を求めよ。
- (d) 振幅が A で、 $x(0) = A \sin \phi$ となる解 $x(t)$ を求めよ。



As shown in the figure, "object a (mass: m_a)" is connected to light spring with a spring constant of k . Assuming that motion of object is limited to the direction of spring, answer the following questions. Here, gravitational acceleration and time are g and t , respectively. Moreover, taking the x -axis in the direction as shown in the figure, the origin of the x -axis is the position of the object a in the natural length of the spring.

- (a) Find the equilibrium position x_a .
- (b) When the object a causes simple harmonic oscillation with x_a as the origin, find the equation of motion for the object a and the general solution.
- (c) Find the solution to satisfy initial conditions, $x(0) = x_0$ and $x'(0) = v_0$.
- (d) Find the solution when $x(0) = A \sin \phi$, assuming that amplitude is A .

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問題3 (Question 3)

熱力学関数の偏微分係数は他の偏微分係数を用いて表すことができる。以下の偏微分係数を、 $\left(\frac{\partial V}{\partial T}\right)_n$ 、 $\left(\frac{\partial V}{\partial p}\right)_n$ を用いて表せ。

- (a) $\left(\frac{\partial T}{\partial V}\right)_p$
- (b) $\left(\frac{\partial T}{\partial p}\right)_V$
- (c) $\left(\frac{\partial S}{\partial V}\right)_T$

A partial derivative of thermodynamic function can be expressed using other partial derivatives.

Express the following partial derivatives using $\left(\frac{\partial V}{\partial T}\right)_p$ and $\left(\frac{\partial V}{\partial p}\right)_T$.

- (a) $\left(\frac{\partial T}{\partial V}\right)_p$
- (b) $\left(\frac{\partial T}{\partial p}\right)_V$
- (c) $\left(\frac{\partial S}{\partial V}\right)_T$