Entrance Examination for the 2019

Department of Civil Engineering,

Graduate School of Engineering, The University of Tokyo

Question Booklet

August 27th 2018 (Monday) 13:00 – 16:00 (180 minutes)

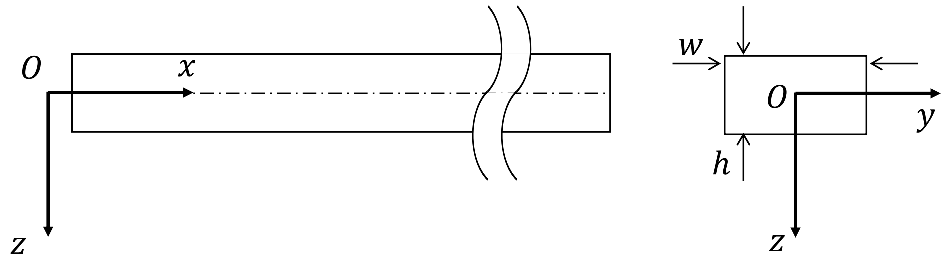
(Field 5 is not provided in English.)

- Please write your answers to questions in two fields which you selected on the questionnaire sheet in advance. <u>If you answer questions in different fields, your answers will not be scored.</u>
- Please use different answer sheets for each question. For each of answer sheet you have, please fill your examinee's number, field number, and question number (e.g. Field 1, Question 1).
- You can use both sides of the answer sheets. When you require additional answer sheets for Fields 1 through 6, please raise your hand. If you use multiple answer sheets for one question, please put sheet number.
- You can ask additional answer sheets for calculation.
- You have to submit this booklet, questionnaire sheet, and all answer sheets (including blank sheets or ones for calculation) after the examination.
- For Field 7 (Mathematics), please select two questions out of six questions. Please note that special answer sheets are provided for Field 7 and that you cannot use additional answer sheets for Field 7.

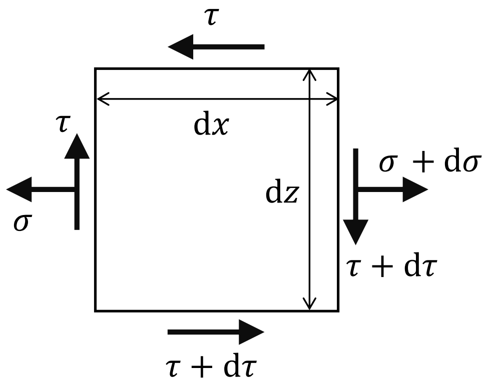
Field 1 (Structures)

Question 1

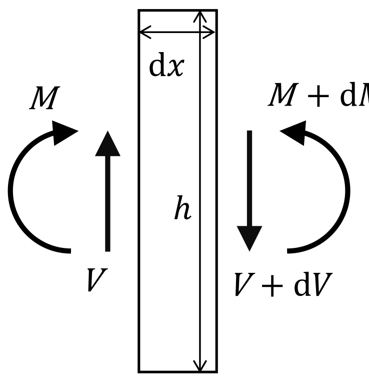
We consider a beam at quasi-static state as shown in Figure 1. The longitudinal direction of the beam is x, and the vertical or horizontal transverse direction of the beam is z or y, respectively, and the cross section of the beam is rectangular with width w and height h. The positive direction of z is downward; see Figure 1a). Answer the following questions.



a) overview of beam and x-, y-, and z-directions



b) normal stress σ and shear stress τ



c) bending moment M and shear force V

Figure 1

(1) As shown in Figure 1b), we take an infinitesimally small portion of length $\mathrm{d}x$ and height $\mathrm{d}z$ from the beam, and consider equilibrium of stress. Show that the normal stress σ and the shear stress τ in the z-direction satisfy the following equilibrium equation in the x-direction.

$$\frac{\partial \sigma}{\partial x} + \frac{\partial \tau}{\partial z} = 0$$

(2) As shown in Figure 1c), we take a small portion of length $\mathrm{d}x$ from the beam. Derive the equilibrium equation of moment that the bending moment M and the shear force V of the cross section satisfy, in the same manner as you show in solving (1).

(3) Derive an expression of M and V in terms of σ and τ, by properly integrating σ and τ on the cross section.

(4) We can compute τ integrating the equilibrium equation of (1) on the cross section. Derive an expression of τ, knowing that $\tau = 0$ is satisfied on the top and bottom of the cross section ($z = \mp h/2$), and that σ is expressed as $\sigma = Az$ in terms of A which is a function of x.

(5) Derive the equilibrium equation of moment of (2) from the equilibrium equation of (1), using the answers of (3) and (4).

(6) In general, a beam has shear strain which is much smaller than normal strain, and we approximate τ as 0. However, the approximation of $\tau \approx 0$ contradicts the two equilibrium equations of (1) and (2). How do you solve this contradiction? Explain your idea of solving the contradiction in around five lines.

Question 2

Answer the following questions.

(1) A cylinder with the mass m, radius r and length l, is floating on stationary water surface as shown in Figure 2. The motion of this cylinder in horizontal and rotational directions is constrained and only vertical (y-direction) motion is allowed. Only gravitational and buoyancy forces are applied to the cylinder. Answer the following questions. The water density is ρ and the gravitational acceleration is g.

a) Obtain the equation of motion of this cylinder in vertical direction.

b) Obtain the natural period of the vertical motion of this cylinder.

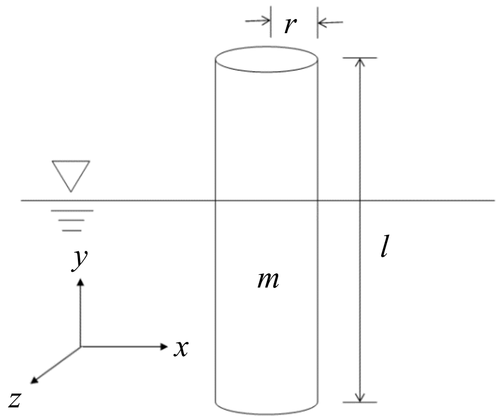


Figure 2

(2) A mass M is supported by two springs with spring constant k and length L as shown in Figure 3. Answer the following questions. You can ignore the mass of the springs and the gravitational force.

a) A horizontal (x-direction) displacement of A is given to this mass at time $t = 0$. The mass has no velocity at $t = 0$. Obtain the expressions for displacement, velocity and acceleration of the mass as a function of time t.

b) A vertical (y-direction) displacement is given to this mass. Obtain the equation of motion of this mass in vertical direction.

c) Simplify the equation of motion obtained in b) assuming the vertical displacement of the mass is small. You may use the approximation $(1 + \delta)^{\alpha} \approx 1 + \alpha\delta$ when $\delta \ll 1$. Based on the simplified equation of motion, describe the characteristic of the vertical motion of the mass in about three lines.

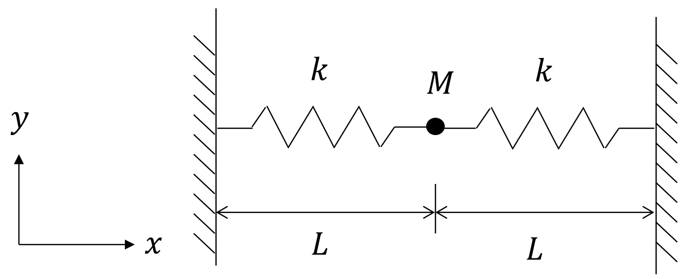


Figure 3

Field 2 (Concrete Engineering and Geotechnical Engineering)

Question 1

Answer the following questions.

(1) One of the assumptions to calculate a flexural capacity of reinforced concrete (RC) beam is that the plane sections remain plane (Bernoulli-Navier hypothesis). Explain the hypothesis and why it is necessary in about five lines. You may use illustrations if necessary.

(2) When a tensile force is applied to steel bars placed in concrete, the average tensile stress-strain relationship of concrete after multiple cracks occur is different from that of concrete without steel bars. Explain how they are different in about seven lines. You must use illustrations.

(3) There are mainly two methods for manufacturing prestressed concrete members, namely pre-tensioning systems and post-tensioning systems. Write two advantages and two disadvantages of the pre-tensioning systems compared to the post-tensioning systems.

(4) Answer whether each of the following statements regarding mix or properties of concrete is correct or wrong. If a statement is wrong, explain the reason in about two lines.

a) When the maximum percentages of packing volume of fine aggregate and coarse aggregate are 56% and 60%, respectively, the maximum percentage of packing volume of mix of these two aggregates is 58%.

b) The volumes of gel pores and interlayer pores in the C-S-H gel generally increase with the progress of cement hydration.

c) Ettringite is one of the typical cement hydrates, and the needle-shaped crystal of ettringite forms mainly by the hydration of alite and aluminate phase. Friedel's salt is produced in the reaction between ettringite and chloride ions, which can fix the chloride ion.

d) As the thermal expansion coefficients of concrete and steel bars are almost the same, we cannot decrease the width of thermal cracks even if we install steel bars as a countermeasure for the thermal cracks.

Question 2

Answer the following questions.

(1) Answer the following questions on an excavation work made by constructing a vertical impermeable wall in level ground consisting of a permeable sandy soil layer, and by removing the soil on one side of the wall. As illustrated in Figure 1, the ground water levels on both sides of the wall are at the ground surface, and the permeable sandy ground is underlain by an impermeable clay layer.

a) Redraw a similar figure on the answer sheet, and add flow net lines and corresponding equipotential lines using solid and broken lines, respectively.

b) Mark the location in the above figure where the largest hydraulic gradient is mobilized in the sandy ground and explain the reason in about three lines.

c) List up two problems that may be potentially induced by the geotechnical behavior of the permeable sandy ground, and explain each of the problems in about five lines, including an example of countermeasure and its working principle.

d) This excavation work may potentially affect the impermeable clay layer as well. Explain its effect on the clay layer and the reason in about three lines.

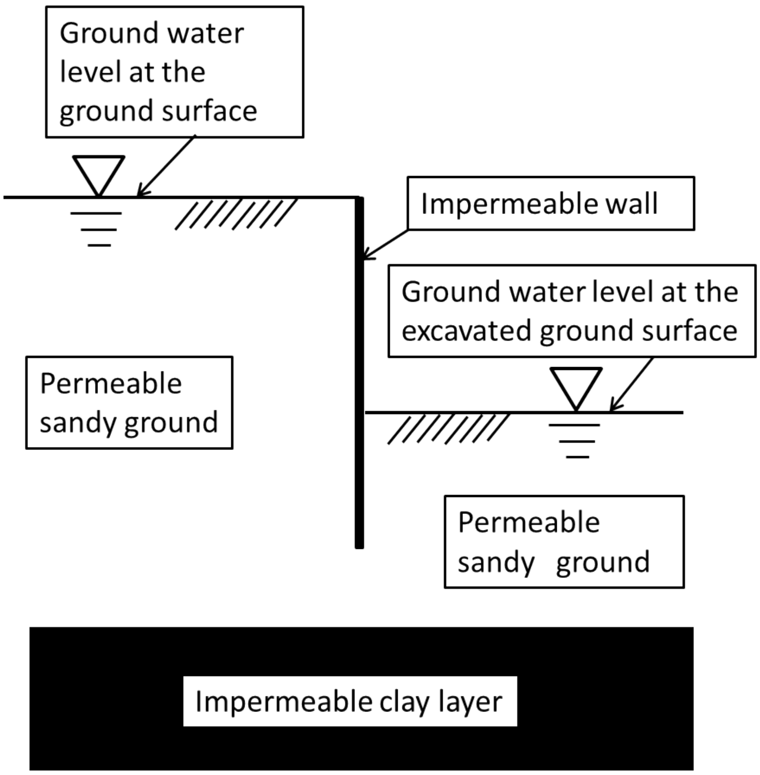


Figure 1

(2) Answer the following questions on earth pressures. If needed, schematic figure(s) may be added.

a) In about three lines each, explain active earth pressure, passive earth pressure and earth pressure at rest, while showing a typical case where each earth pressure is mobilized.

b) In about five lines, explain the procedures to evaluate the resultant force of passive earth pressure exerted to a vertical and smooth back face of soil retaining walls, based on Rankine's earth pressure theory.

c) In about five lines, explain the procedures to evaluate the resultant force of passive earth pressure exerted to a vertical and smooth back face of soil retaining walls, based on Coulomb's earth pressure theory.

d) On each of the factors/properties listed as d-1 through d-5 below, by rewriting and completing the following table on the answer sheet, indicate whether or not it can be considered/evaluated by the Rankine's and/or Coulomb's earth pressure theories.

d-1: Inclination angle of the back face of soil retaining walls

d-2: Friction mobilized at the back face of soil retaining walls

d-3: Cohesion of the backfill soils

d-4: Seismic inertia force exerted to the backfill soils

d-5: Vertical distribution of earth pressure

Factors/ properties	Rankine's earth pressure theory	Coulomb's earth pressure theory
d-1		
d-2		
d-3		
d-4		
d-5		

○: can be considered/evaluated, —: cannot be considered/evaluated

Field 3 (Hydrosphere Engineering)

Question 1

Read the paragraphs about the theory of open channel flow and the jet streams below, and answer each question about the underlined parts 1) to 6). You may define additional variables if necessary.

In the steady open channel flow, the energy conservation law can be expressed from the equation of motion[1)] obtained by assuming the hydrostatic approximation. The energy expressed as the water head with reference to the channel floor is called specific energy. The critical water depth can be defined from the relation between specific energy and water depth, and subcritical flow and supercritical flow can be defined[2)] by using Froude number. The phenomenon that occurs when transitioning from a state of high specific energy to a state of low specific energy is called hydraulic jump[3)].

Here, we shall apply this theory of open channel flow to the jet streams of the earth. Jet stream is a strong wind band that flows eastward in the middle and high latitudes of the earth's upper troposphere. Since the earth rotates on its own axis, the apparent force[4)] works in the direction horizontally perpendicular to the wind direction, and the pressure gradient force works in the opposite direction to satisfy the balance of the forces. Open channel flow and jet streams will have analogies[5)], if the water depth in the open channel is regarded as the horizontal width of the jet stream. For example, it is possible to regard a state in which the jet stream has a large width as a subcritical flow, a state with a small width as a supercritical flow, and a state in which the sudden width changes can be compared to a hydraulic jump. The dimensionless quantity called Rossby-Froude number is an analogical counterpart of the Froude number in open channel flow. The sudden change in the width of jet stream is greatly related to the weather in Japan as a phenomenon called "blocking."[6)]

(1) With respect to 1), the equations of motion in the tangential direction and the normal direction of the streamline of a perfect fluid are expressed by the following equations. From these equations, derive the conservation law of energy in a steady open channel flow.

$$\frac{1}{g}\frac{\partial v_s}{\partial t} + \frac{1}{2g}\frac{\partial v^2}{\partial s} = -\frac{\partial}{\partial s}\left(\frac{p}{\rho g} + z\right)$$

$$\frac{1}{g}\frac{\partial v_n}{\partial t} + \frac{1}{g}\frac{v^2}{r} = -\frac{\partial}{\partial n}\left(\frac{p}{\rho g} + z\right)$$

Here, s and n denote the tangential direction and normal direction of the streamline, respectively, v is the magnitude of flow velocity, and v_s and v_n are the velocity components in the tangential direction and the normal direction, respectively. p is the pressure, z is the elevation of the channel floor, g is the gravitational acceleration, ρ is the density, and r is the radius of curvature of streamline.

(2) Regarding 2), illustrate the relationship between the water depth h and the specific energy E in case of constant unit width flow rate q. Also, indicate the critical water depth h_c and the ranges of subcritical flow and supercritical flow in the illustration.

(3) Regarding 3), assume that a hydraulic jump occurred in one section of the open channel with a horizontal channel floor. Water depths before and after jumping were 0.2 m and 0.8 m, respectively. At this time, calculate the unit width flow rate q through the open channel and the specific energy loss ΔE and answer them with two significant figures, respectively. Use $g = 9.8\ \mathrm{m/s^2}$.

(4) Regarding 4), this apparent force is known as "Coriolis force", and its horizontal magnitude is

fV, where V is horizontal wind speed relative to the earth's surface and $f = 2\Omega \sin\varphi$ with Ω, the angular velocity of rotation of the earth, and φ, latitude. In addition, it is assumed that the latitudinal dependence in the target area is linearly approximated ($f = f_0 + \beta y$; where $f_0 = 2\Omega \sin\varphi_0$, and y is the horizontal meridional distance from the latitude φ_0 (polar direction is positive) [m]). This is called β-plane approximation. Calculate the value of β at latitude 45 degrees and answer it with two significant figures. Use $\sin 45° = 0.71$, the radius of the earth 6.4×10^6 m, and $\pi = 3.14$.

(5) Regarding 5), if the wind speed u is uniform in the jet stream with the width of a, the Rossby-Froude number corresponding to the Froude number in the open channel is expressed as $R_F = 12\,u/\beta a^2$. Assume that the jet stream is at the state corresponding to critical flow in the steady open channel flow and it has a wind speed of 12 m/s. Calculate the width of the jet stream at that time using β calculated in (4) and answer it with one significant figure.

(6) Regarding 6), "blocking" is analogically equivalent to hydraulic jump. Specific energy decreases by a hydraulic jump in open channel flow. What kind of flow is considered to be occurring in the upper air during the blocking phenomenon? Answer it in about two lines. In addition, name two specific examples of hydro-meteorological phenomena that can occur when a blocking sits over Japan, and describe the physical occurrence mechanisms and their social influences in about 12 lines in total.

Question 2

Consider incompressible viscous flows between a circular pipe of radius $2a$ and a cylinder of radius a sharing a common axis shown in Figure 1. There is no gravitational force acting on the fluid.

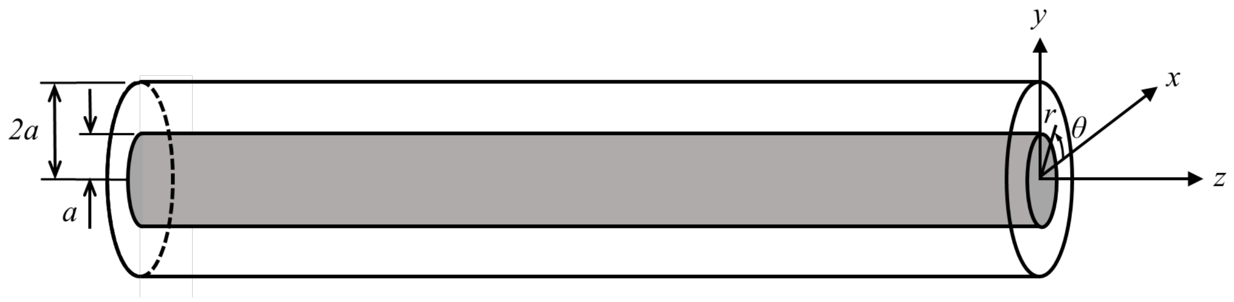


Figure 1

The following continuity and momentum equations in cylindrical coordinates (r, θ, z) hold for laminar pipe flows in general.

Continuity equation:

$$\frac{\partial u_r}{\partial r}+\frac{u_r}{r}+\frac{1}{r}\frac{\partial u_\theta}{\partial \theta}+\frac{\partial u_z}{\partial z}=0$$

Momentum equations:

$$\rho\left(\frac{\partial u_r}{\partial t}+u_r\frac{\partial u_r}{\partial r}+\frac{u_\theta}{r}\frac{\partial u_r}{\partial \theta}-\frac{u_\theta^2}{r}+u_z\frac{\partial u_r}{\partial z}\right)=-\frac{\partial p}{\partial r}+\mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial u_r}{\partial r}\right)-\frac{u_r}{r^2}+\frac{1}{r^2}\frac{\partial^2 u_r}{\partial \theta^2}-\frac{2}{r^2}\frac{\partial u_\theta}{\partial \theta}+\frac{\partial^2 u_r}{\partial z^2}\right]$$

$$\rho\left(\frac{\partial u_\theta}{\partial t}+u_r\frac{\partial u_\theta}{\partial r}+\frac{u_\theta}{r}\frac{\partial u_\theta}{\partial \theta}+\frac{u_r u_\theta}{r}+u_z\frac{\partial u_\theta}{\partial z}\right)=-\frac{1}{r}\frac{\partial p}{\partial \theta}+\mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial u_\theta}{\partial r}\right)-\frac{u_\theta}{r^2}+\frac{1}{r^2}\frac{\partial^2 u_\theta}{\partial \theta^2}+\frac{2}{r^2}\frac{\partial u_r}{\partial \theta}+\frac{\partial^2 u_\theta}{\partial z^2}\right]$$

$$\rho\left(\frac{\partial u_z}{\partial t}+u_r\frac{\partial u_z}{\partial r}+\frac{u_\theta}{r}\frac{\partial u_z}{\partial \theta}+u_z\frac{\partial u_z}{\partial z}\right)=-\frac{\partial p}{\partial z}+\mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial u_z}{\partial r}\right)+\frac{1}{r^2}\frac{\partial^2 u_z}{\partial \theta^2}+\frac{\partial^2 u_z}{\partial z^2}\right]$$

Here, z is taken as the axis of the pipe, r is the radial distance from the z-axis and θ is the angle from the positive x-axis as shown in Figure 1. (u_r, u_θ, u_z) represent the radial, tangential and axial velocity components, p is pressure, ρ and μ are density and viscosity of the fluid, respectively. The pipe and the cylinder are sufficiently long. Answer the following questions regarding laminar flows between the pipe and the cylinder.

(1) Show that the radial velocity u_r is zero for axially uniform and axisymmetric flows between the pipe and the cylinder from the continuity equation.

(2) We generate a steady circular flow between the pipe and the cylinder by rotating the cylinder about z-axis at a constant angular velocity ω with the pipe fixed. Let this flow satisfy the condition in (1) and answer the following questions.

a) Simplify the momentum equation for the tangential velocity u_θ under the given conditions.
b) Describe the boundary conditions for the tangential velocity u_θ.
c) Find the distribution of the tangential velocity u_θ between the pipe and the cylinder.
d) Find the pressure difference between the inner surface of the pipe ($r = 2a$) and the cylinder surface ($r = a$).

(3) We stop the rotation and then generate a steady axial flow between the pipe and the cylinder by applying pressure from the negative side of z-axis using a pump to make a constant axial pressure gradient $G = -\partial p/\partial z$ (> 0) along the flow. Let this flow satisfy the condition in (1) and answer the following questions.

a) Simplify the momentum equation for the axial velocity u_z under the given conditions.
b) Describe the boundary conditions for the axial velocity u_z.
c) Find the distribution of the axial velocity u_z between the pipe and the cylinder.
d) Find the axial flow discharge between the pipe and the cylinder.
e) Find the flow-induced axial force on the cylinder per its unit length.

Field 4 (Transportation and Spatial Information Engineering)

Question 1

Answer the following questions.

(1) Answer the following questions about the transportation planning of a local city.

a) The utility function of holiday activities in the central urban area (g) is expressed as $U_g = V_g + \varepsilon_g$, where U_g is utility of central urban area, V_g is deterministic term and ε_g is error term, the utility function of activities at suburban shopping center (t) can be described by $U_t = V_t + \varepsilon_t$, where U_t is the utility of suburban shopping center, V_t is deterministic term and ε_t is error term. Derive an expression for the binary choice probability P_g of choosing the central urban area in holiday activity choice for a probability density function of ε' ($f(\varepsilon')$) shown in Figure 1, when $\varepsilon' = \varepsilon_g - \varepsilon_t$. For the holiday activity, no choice other than g and t is considered.

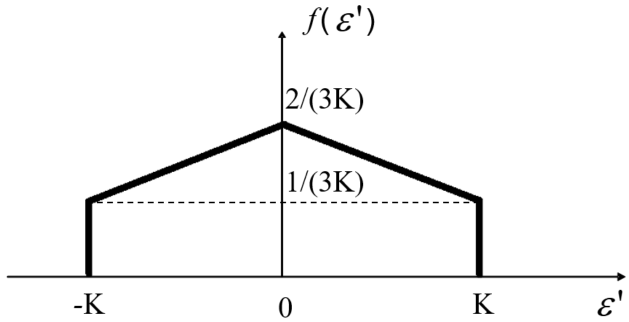


Figure 1 Probability density function of ε' (K is constant)

b) Assuming independent and identically distributed Gumbel (i.i.d. Gumbel) $e^{-\varepsilon}\ e^{-e^{-\varepsilon}}$ for the error distribution, derive the choosing probability and answer within eight lines about how the difference in variance of the error distribution affects the choosing probability.

c) Propose one effective transportation policy to improve access to central urban area, survey methods for policy evaluation and evaluation analysis method within five lines each.

d) Since shopping refugee problems occurred in an old residential of suburbs, it was decided to make a public transport network plan. When you make a public transport network plan, give three important transportation policies from the viewpoint of "cooperation", answer within five lines each.

(2) Read the following sentences and select correct combination of wrong-correct phrases with underline from A to E.

Although it is possible to improve congestion by collecting congestion tax from road users and internalizing external diseconomies, income redistribution increases ① economic welfare unless it reduces the overall output economic. This is based on the principle of ② Pigou's first proposition. This proposition is derived from the law of diminishing marginal utility and income redistribution can satisfy ③ the stronger desire of the rich. In order ④ to correct the internal effect which increases the total of desire satisfaction, we grant subsidies on ⑤ negative external effects and tax on ⑥ positive external effects. At this time, it is necessary to maximize ⑦ "total benefit" as a whole society which is equal to "user benefits" minus “social expenses”

(combined costs of external expenses which are ⑧ positive effects on society and normal expenses.)

	①	②	③	④	⑤	⑥	⑦	⑧
A	Wrong	Wrong	Wrong	Wrong	Wrong	Wrong	Wrong	Wrong
B	Wrong	Wrong	Wrong	Correct	Correct	Correct	Correct	Wrong
C	Wrong	Wrong	Wrong	Correct	Wrong	Correct	Correct	Wrong
D	Correct	Wrong	Wrong	Wrong	Correct	Wrong	Wrong	Wrong
E	Wrong	Correct	Correct	Correct	Wrong	Wrong	Correct	Correct

Question 2

Answer the following questions.

(1) Explain the global geodetic reference system in about eight lines.

(2) Explain a Real Time Kinematic positioning (RTK positioning) by using all of the following words:
carrier phase relative positioning, integer bias, On the Fly method, wide lane.

(3) Answer the following questions about orientation of photogrammetry.
  a) Write five exterior and interior orientation elements in total.
  b) Write the collinearity condition equation. Variables should be defined by yourself.
  c) Explain the difference between orientation of a single photograph with only exterior orientation elements and that with exterior and interior orientation elements, by using the collinearity condition equation.

(4) Explain the false color composite of satellite remote sensing data in about five lines. Additionally, write an example of the false color composite, and explain its application in about eight lines in total.

Field 6 (International Project and Management)

Question 1

In developing countries, migration from rural areas to urban areas has been often observed. Answer the following questions related to this.

(1) Describe a mechanism how the migration occurs from rural areas to urban areas in approximately eight lines, using all the following words. You may add diagrams and/or tables if necessary.

agricultural sector, manufacturing sector, labor demand, wage

(2) One of issues caused by excess migrations from rural areas to urban areas is an economic disparity across regions. Explain expected roles of infrastructure to mitigate the interregional economic disparity in approximately eight lines.

(3) In some developing countries, large migration to a specific city produces a megacity with over 10 million inhabitants. Raise four potential reasons that the primary city has significantly larger population than any other cities in a country, and explain them in approximately three lines for each.

(4) Informal sector often takes important roles in megacities of developing countries. Show three positive and three negative impacts of the informal sector on cities, respectively.

Question 2

Read the following sentences on "Infrastructure Systems Management," and answer the questions related to the underlined parts.

Infrastructure facilities are constructed to deliver public services for supporting people's life and industrial activities. In order to construct infrastructure facilities and to fulfill their functions, it is necessary to construct <u>a project cycle</u>① appropriately, and to formulate the entire system, which includes <u>social system</u>②, <u>organization</u>③ and <u>stakeholder activities</u>④ concerning the project cycle. "Infrastructure Systems Management" is defined as activities required for making the <u>infrastructure systems</u>⑤ to satisfy social needs.

(1) Regarding the underlined part ①, explain issues to be considered in the design stage for reducing cost in the maintenance stage of a project cycle citing their reasons, in about six lines.

(2) Regarding the underlined part ②, Private Finance Initiative (PFI) is a system to utilize private funds for infrastructure projects. Explain three main players in this system and their motivations to participate in a PFI project in about six lines.

(3) Regarding the underlined part ③, Construction Management (CM) is utilized when it is difficult to establish a sufficient team for a project in a project owner's organization. Explain features of CM and its contract type in about five lines.

(4) Regarding the underlined part ④, Early Contractor Involvement (ECI) is a system utilized in large and complex projects. Explain features of ECI and its advantages in comparison to a traditional system in about six lines.

(5) Regarding the underlined part ⑤, discuss the infrastructure systems for the society where maintenance projects are dominant, focusing on the differences between new development projects and maintenance projects, in about eight lines.