Entrance Examination for the 2018

Department of Civil Engineering,

Graduate School of Engineering, The University of Tokyo

Question Booklet

August 28th 2017 (Monday) 13:00 - 16:00 (180 minutes)

(Fields 5 and 6 are not provided in English.)

- ○ Please write your answers to questions in two fields which you selected on the questionnaire sheet in advance. If you answer questions in different fields, your answers will not be scored.
- ○ 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 the reverse side of 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

Consider a horizontal beam. The elastic modulus (Young's modulus), the second moment of area, and the span of the beam are denoted by E, I, and L, respectively.

(1) Suppose that the beam is subjected to a concentrated load, P, at the middle of the span. Write a differential equation for the vertical deflection of the beam, w. We take the x-axis along the beam, and w is a function of x; the left and right ends are $x = 0$ and $x = L$, respectively.

(2) Write the boundary conditions when the beam is simply supported.

(3) When the beam ends are fixed, w at the middle ($x = L/2$) becomes smaller compared with the case when the beam is simply supported.

a) Write the boundary conditions when the beam ends are fixed.

b) Do the shear force and the bending moment that act at the beam ends increase when the boundary conditions are changed? Explain your answer for the shear force and your answer for the bending moment.

c) In view of b), explain briefly the reason that w at the middle becomes smaller when the beam ends are fixed.

(4) Suppose that a certain portion of the cross section at the middle is lost due to cracking, and the second moment of area at that point is decreased. When the beam is simply supported, does w at the middle ($x = L/2$) become larger? Explain your answer briefly.

Question 2

A vehicle is modeled as a single-degree-of-freedom system shown in Figure 1. The mass and the spring constant are denoted by m and k. t denotes the temporal coordinate and x denotes the spatial coordinate in the moving direction. The gravitational acceleration is g. The vehicle speed v is constant; therefore $x = vt$. $u_g(x) = u_g(vt)$ represents the road profile. $y(t)$ represents the vertical displacement of the mass from the static equilibrium point when $u_g(x)=0$. Answers may be simplified by using $\omega^2 = \frac{k}{m}$. Answer the following questions.

(1) Derive the equation of motion of this vehicle in the vertical direction.

(2) Express the force $f(t)$, which the vehicle exerts on the road, including the static component. The force is positive if the spring is in compression. $u_g(vt)$ and $y(t)$ may be used.

(3) Obtain the free vibration response $y(t)$ of the vehicle for $t > 0$ when the vehicle passes over a flat road represented by equation [1]. The initial conditions are $y(0) = y_0$ and $\dot{y}(0) = \dot{y}_0$.

$$u_g(x) = 0 \qquad [1]$$

(4) Obtain the vehicle response $y(t)$ for $0 \le t \le \frac{\pi}{\omega}$ and $\frac{\pi}{\omega} < t$, respectively, when the vehicle passes over a concave road represented by equation [2]. The initial conditions are $y(0) = 0$ and $\dot{y}(0) = 0$. The particular solution $Ct\cos\omega t$ for $0 \le t \le \frac{\pi}{\omega}$ may be utilized. C is an unknown constant.

$$u_g(x) = \begin{cases} 0 & (x < 0) \\ -\sin\left(\frac{\omega x}{v}\right) & \left(0 \le x \le \frac{\pi v}{\omega}\right) \\ 0 & \left(\frac{\pi v}{\omega} < x\right) \end{cases} \qquad [2]$$

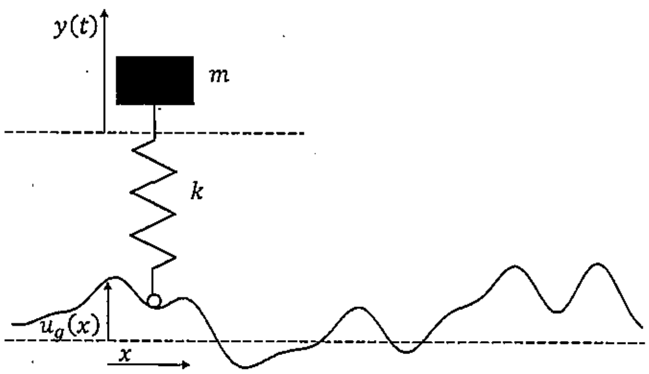


Figure 1

Field 2 (Concrete Engineering and Geotechnical Engineering)

Question 1

Answer the following questions.

(1) Calculate the flexural capacity of the section of a reinforced concrete (RC) member with properties given below, when failure occurs only with flexural moment. Reinforcing steels are arranged in the tensile side only and the compressive side does not have any reinforcing steels. Do not use safety factors.

Cross section height of the RC member : 50 cm
Cross section width of the RC member : 30 cm
Total cross section area of tensile reinforcements : $A_s = 30\ \text{cm}^2$
Effective depth : 45 cm
Yielding strength of reinforcement : $f_y = 400\ \text{N/mm}^2$
Elastic modulus of reinforcement : $E_s = 200{,}000\ \text{N/mm}^2$
Compressive strength of concrete : $f'_c = 40\ \text{N/mm}^2$
Ultimate compressive failure strain of concrete : $\varepsilon'_u = 0.0035$

(2) Figure 1 is a schematic diagram which shows occurrences of internal cracks at the center part of a long RC member subjected to tension to induce cracks. The both side parts of the member are not included in this figure. Suppose the length of the RC member is more than 1 m, the diameter of the RC section is around 100 mm and the embedded deformed bar is D13. Answer the following questions.

a) What is the technical term of short crack which initiates from the lugs of the deformed bar.
b) Suppose the embedded deformed bar in Figure 1 is replaced by a long bolt having the surface pattern shown in Figure 2 and the replaced long bolt has the same diameter with the deformed bar. Draw a schematic diagram of internal cracks after tension is applied to the member in which a long bolt is embedded and explain the diagram in 5 - 8 lines.

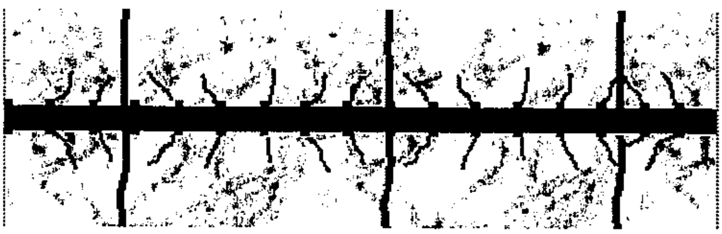


Figure 1

"Magnified view"

Figure 2

(3) Figure 3 shows water flowing situation on the surface of RC pier when rain falls and concrete cover spalling takes place at some parts. This pier is not subjected to any salt attack. Answer the following questions.

a) Concrete cover spalling takes place only in the right side (Y side) of this pier. Give the reason in around 5 lines.
b) Compare the left side (X side) and the right side (Y side) of this column, and give the answer and reasons which side got faster carbonation of concrete in around 5 lines.
c) By considering the occurrence of deterioration shown in Figure 3, point out current problems in verification of the durability design for a RC member subjected to this kind of environment in 8 - 15 lines.

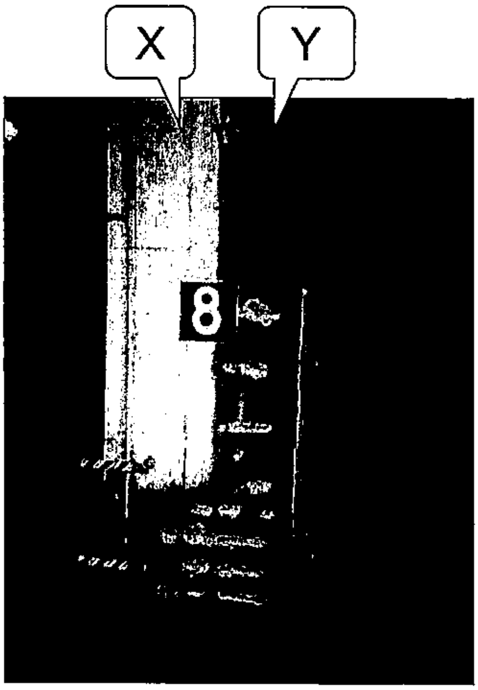


Figure 3

Question 2

Answer the following questions.

(1) Answer the following questions on the compaction characteristics of a sandy soil that has the specific gravity of soil particle G_s= 2.4.

a) Write down the equation of zero air voids curve of the soil in terms of the dry density, ρ_d, and the water content, w.

b) In compaction tests, the maximum dry density is 1.8 g/cm^3 at the degree of saturation, S_r, of 80%. Determine the optimum water content under the same circumstance.

c) In tests for minimum and maximum densities of sands, the tested soil exhibited a minimum density of 1.2 g/cm^3, and a maximum density of 1.6 g/cm^3. Determine the relative density, D_r, of the tested sample if the dry density, ρ_d, is 1.5 g/cm^3.

d) Specimens A and B are prepared under the same compaction curve at different water content, while they have the same dry density as shown in Figure 4. Then triaxial compression tests are performed on the specimens while maintaining the initial water content. Choose the expected result of shear strength, τ_A and τ_B, of the specimens A and B from the following three, and describe the reason in about 5 lines.

① $\tau_A = \tau_B$ ② $\tau_A > \tau_B$ ③ $\tau_A < \tau_B$

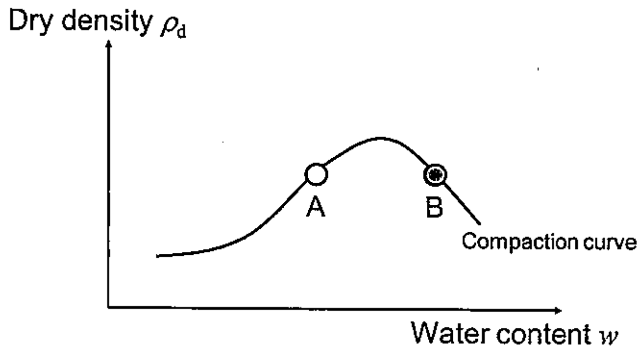


Figure 4

(2) Answer the following questions on the soil consolidation.

a) In general, the time rate of consolidation of clay is much lower than that of sand. Describe the reason in about 8 lines based on Terzaghi's one-dimensional consolidation equation,

$$\frac{\partial u_e}{\partial t} = c_v \frac{\partial^2 u_e}{\partial z^2}$$

where u_e is the excess pore water pressure, t is time, c_v is the coefficient of consolidation and z is the depth of soil.

b) Figure 5 shows the results of the oedometer test. Answer the following questions.
- What is the technical term of the stress in the vicinity of a maximum curvature point of the consolidation curve indicated by arrow A?
- What are the technical terms of the soils in the lower and higher stress regions than the above stress state, respectively?

c) According to the test results shown in Figure 5, the value of c_v significantly decreased in the vicinity of the stress indicated by arrow A. Discuss the reason in about 8 lines.

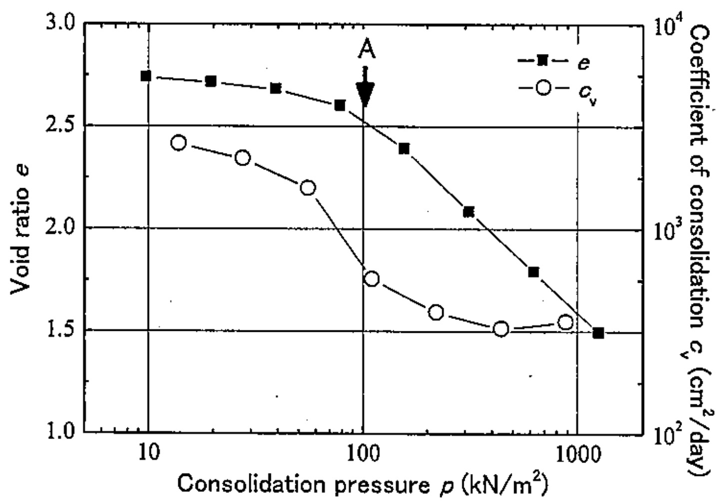


Figure 5

(3) Answer the following questions on the soil liquefaction.

a) An earthquake hit a level ground of sandy soil with the saturated unit weight, γ_{sat}, of 20 kN/m^3 and the liquefaction resistance ratio (cyclic resistance ratio), R, of 0.37, where the ground water level was equal to the ground surface. Assuming that the horizontal seismic coefficient at the ground surface, k_s, is 0.20, calculate the thickness of liquefied soil layer by using a simplified liquefaction assessment method (F_L method). Use the following conditions in the calculation.
- Unit weight of water, γ_w= 10 kN/m^3
- Reduction factor of shear stress ratio (L) during earthquake, r_d= 1.0 – 0.015z, where z is depth in meters.

b) Lattice-type cement mixing method is one of the common soil improvement techniques against liquefaction. Describe the improvement mechanism of this method in about 5 lines.

Field 3 (Hydrosphere Engineering)

Question 1

Answer the following questions.

(1) Dam construction changes sediment transport characteristics and has various impacts on the entire fluvial systems.

a) Explain possible changes of sediment transport characteristics and how these changes will affect disaster risks at the upstream of the dam, at the downstream of the dam, and in the coastal area (2~3 lines each).

b) Explain three counter measures against dam sedimentation (2~3 lines each).

(2) One of the functions of dams for flood control and/or water resources management is to release the water to the rivers when the river discharge is not sufficient to appropriately maintain the intrinsic functions of the rivers. List five such functions of rivers that should be considered when deciding the optimum outflow rate of the water released from dams.

(3) Functional enhancement of existing dams is considered as one of effective measures to reduce the water-related disaster risks and to keep better water resource management under the future extreme weather and climate change. List and explain two structural and two non-structural measures for such functional enhancement of the dams (2-3 lines each).

(4) As shown in Figure 1, a hydraulic power plant generates the electricity by using the water running through a conduit connected to the dam. Answer the following questions.

a) A facility called surge tank is connected to the conduit. By using Bernoulli's equation, explain the reason why this facility is required.

b) As shown in Figure 1, H is the height from the outlet of the electric power plant to the water level in the reservoir, d is the diameter of the conduit, f is the coefficient of friction loss of the conduit, K_e is the coefficient of entrance loss, K_b is the coefficient of bend loss, ρ is the density of the fluid, g is a gravity acceleration and L_1, L_2 and L_3 are the lengths of the conduits in the order from the upstream, respectively. Determine the effective head H_T (total energy that can be utilized for the power generation) where v is the flow velocity in the conduit. Assume that the head losses around the surge tank and inside the hydraulic power plant are negligibly small. Define any physical quantities if necessary.

c) Express the equation which determines the electric power generation rate, T. Here, use the variables given in the question (4) b) and η, the power generation efficiency. Assume that T is determined as a product of η and the rate of the work done by the effective head, H_T.

d) Determine the flow velocity which maximizes the electric power generation rate, T.

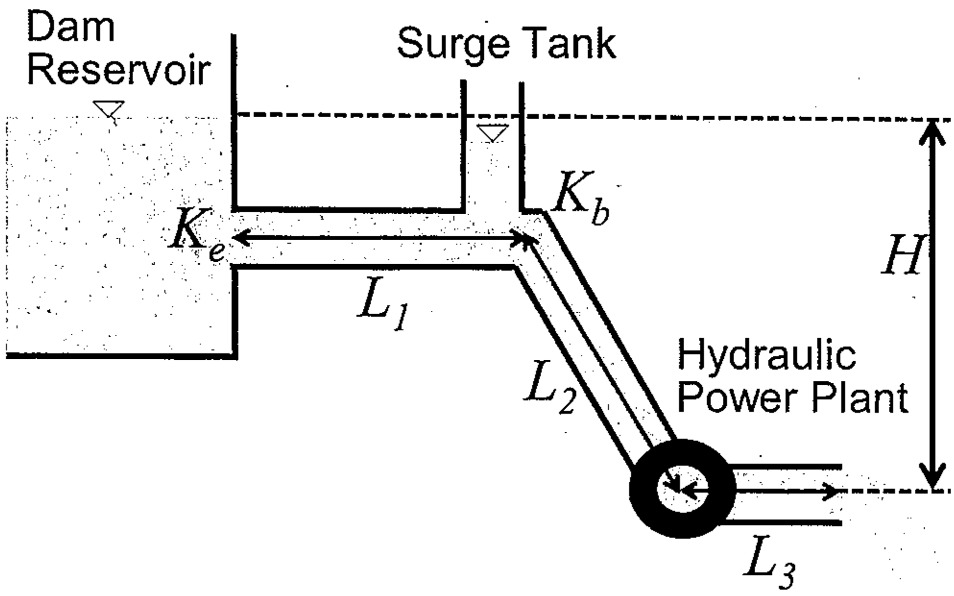

Dam
Reservoir
Surge Tank
K_b
K_e
L_1
H
L_2
Hydraulic
Power Plant
L_3

Figure 1

Question 2

This question focuses on the storm surge characteristics when a typhoon approaches the long-straight coast shown in Figure 2. In the figure, all the properties are assumed uniform in the alongshore direction, i.e., in the direction perpendicular to this paper. Here, x and z, are the horizontal and vertical coordinates originated from the point, O, located at the still water level, and are positive in the landward and the upward directions, respectively. Moreover, u and w are the fluid velocity components in x and z directions, h is the still water depth, η is the instantaneous water level based on the still water level, p is a pressure, g is gravity acceleration and ρ is the density of the fluid. Answer the following questions.

(1) Express the mass-conservation equation of the fluid and derive the continuity equation from the mass conservation equation under the assumption of incompressible fluid.

(2) Express the momentum equations in the horizontal and vertical directions, respectively, and explain the physical meanings of each term.

(3) In the cases of tsunami and storm surge, the horizontal length scale can be assumed to be much longer than the vertical length scale. Under this assumption, the following non-linear shallow water equations can be derived from the continuity and momentum equations described in the questions (1) and (2), respectively.

$$\frac{\partial \eta}{\partial t}=-\frac{\partial Q}{\partial x}=-\frac{\partial (UD)}{\partial x} \qquad [1]$$

$$\frac{\partial Q}{\partial t}+\frac{\partial}{\partial x}\left(\frac{Q^2}{D}\right)=-\frac{1}{\rho}\int_{-h}^{\eta}\frac{\partial p}{\partial x}dz+\frac{\tau_{sx}}{\rho}-\frac{\tau_{bx}}{\rho} \qquad [2]$$

Here, Q is the horizontal volume flux per unit width, $D=h+\eta$ is the total water depth, U is the depth-averaged horizontal velocity, and τ_{sx} and τ_{bx} are the horizontal shear stresses acting on the water surface and the water bed, respectively.

a) Apply the assumption of non-linear shallow water equations to the vertical momentum equation expressed in the question (2) and determine the fluid pressure, p, at arbitrary water depth, z, as a function of the variables such as atmospheric pressure, p_a, and the water level, η.

b) Determine the horizontal force acting on the fluid particle at point A in Figure 2, located on the water bed, as a function of the variables such as atmospheric pressure, p_a, and the water level, η. Define any physical quantities if necessary.

(4) Cross-shore distribution of the atmospheric pressure, p_a, at the water surface shown in Figure 2 is determined by the following equation [3].

$$p_a=\frac{p_0-p_L}{2}\cos\left(\frac{\pi}{L}x\right)+\frac{p_0+p_L}{2} \qquad (0\leq x\leq L) \qquad [3]$$

where p_0 and p_L are atmospheric pressure at location $x=0$ and $x=L$, respectively.

Besides this pressure distribution, wind-induced horizontal shear stress, τ_{sx}, is also acting on the water surface. Under this condition, the water level gradually changed and reached to the steady state condition.

a) Assuming that the water level at the origin, O, does not change, i.e., $\eta=0$ at x=0, determine the water level, η, in front of the seawall, i.e., at x=L, under the steady state condition as functions of the variables such as h, L, p_0, p_L and τ_{sx}. Here assume that the water level, η, is negligibly small compared to the water depth, h, and the total water depth, D, can be approximated by h.

b) Discuss in 3~5 lines how the water level determined in the question (4) a) varies with h and L and how this feature is related to the characteristics of the Bay of Bengal and the Gulf of Mexico, where are known to be prone to suffering severe storm surge disaster.

(5) Plantation of mangroves is considered as one of counter measures against storm surge and tsunami. Assuming that mangroves can increase the absolute value of τ_{bx}, in the equation [2], explain in 3~5 lines how the mangroves affect the water level change in front of the seawall, determined in the question (4) a).

(6) San Pedro Bay is a relatively small-scale bay where suffered severe inundation due to the storm surge induced by Super Typhoon Haiyan landed on the Philippines in 2013. The bay is open to the south and Haiyan passed the south side of the bay from the east to the west. Under this condition, the wind around San Pedro Bay suddenly changed from the north wind to the south wind. Following the case in San Pedro Bay, the acting direction of τ_{sx} was suddenly changed from the offshore-ward to the landward while all the other conditions were set identical to the ones in question (4) a). Under this condition, the computed maximum water level in front of the seawall became higher than the one determined in question (4) a). Discuss in 4~10 lines the reasons why the maximum water level became higher than that of question (4) a) in a qualitative manner using equations [1] and [2]. Assume that the absolute value of τ_{sx} remains constant and identical to the one in the question (4) a) even when the acting direction of τ_{sx} suddenly changes.

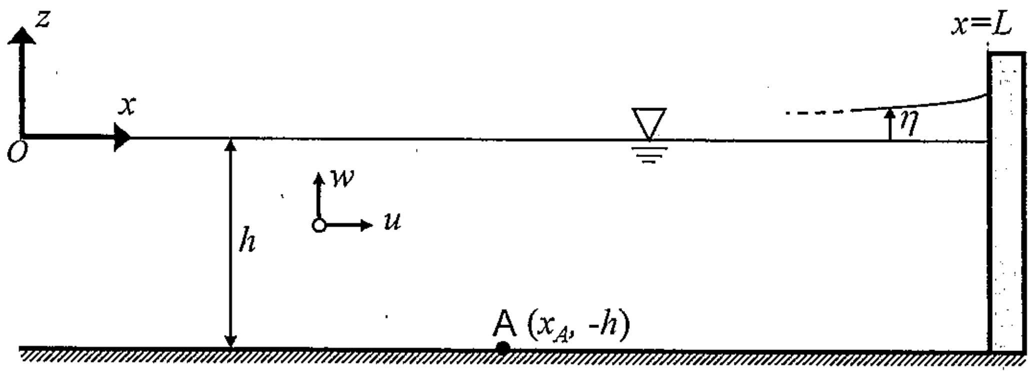


Figure 2

Field 4 (Economics, Spatial Information Engineering)

Question 1

Answer the following questions.

(1) Suppose that a new road is introduced in addition to an existing toll-free road, both of which connect two given points. Travel-time saving is expected for road users from the introduction of the new road. No traffic congestion is assumed in those roads. Then answer the following questions regarding economic benefit stemming from the road introduction.

a) Show a method to compute the economic benefit when the newly introduced road is a toll-free road.

b) When the newly introduced road is a toll road where road users are required to pay a given toll for using the road, is the economic benefit in this case different from that in the above case a)? And explain the reason.

(2) Let us consider a general equilibrium where there are a consumer and a firm with two goods: time and consumption good. Assume the firm is owned by the consumer. Answer the following questions.

a) The firm produces the consumption good by inputting work time l only under a given price vector. Let a production function be $y = f(l)$, the price of consumption good be p, and wage rate be w; and assume the production function is the quasi-concave and increasing function. Then, formulate the firm's profit maximization and show the first-order optimality condition(s). Additionally, illustrate a diagram that indicates the profit maximization.

b) The consumer consumes leisure time and the consumption good that is produced by the firm. The consumer is assumed to own time only as the initial endowment. Let a utility function be $u(T - l, x)$ where T denotes a time constraint such as 24 hours and x denotes an amount of the consumption good. The utility function is assumed to be the quasi-concave and increasing function. Then, formulate the consumer's utility maximization and show the first-order optimality condition(s). Additionally, illustrate a diagram that indicates the utility maximization.

c) Illustrate the general equilibrium point by combining the two diagrams that you have produced in a) and b).

Question 2

Answer the following questions.

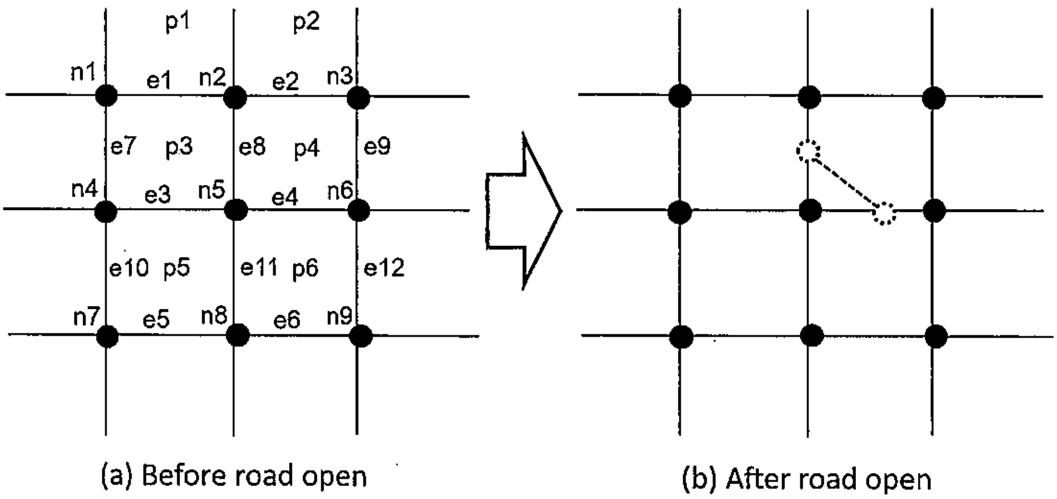
(1) Answer the following questions about Global Positioning System (GPS).

a) Write three methods of global positioning. Explain the principle and accuracy of each method in about 9 lines, in total.

b) Assume that we have a large volume of GPS data of moving people (e.g. data of millions people for a period of one year, at one minute intervals). We consider to segment the GPS data into trip data by destination and store into database for better searchability. Explain the typical steps of data processing involved, within 15 lines.

(2) Answer the following questions about the data structure of spatial information.

a) Assume that topological structure of the road network shown in Figure 1(a) is changed by a road open (dashed line) as shown in Figure 1(b). Describe the changes of the edges and polygons in the topological structures due to the road open. You may follow the notation given in the box of Figure 1. Nodes (n), edges (e) and polygons (p) before road open are represented in Figure 1(a). Furthermore, add appropriate numbers for new nodes, edges and polygons in the description.



Description example of topological structure
(Edge) e7:n1,n4
(Polygon) p3:e1,e8,e3,e7

Figure 1 Topological structure of road network ((a) shows the structure before road open and (b) shows after road open. Dashed line indicates the new road.)

b) Recent Japanese national maps usually don't include specific topological structures, while some of national maps had them in the past. Explain the reason within 7 lines.

(3) Assume that you are the Deputy Assistant Minister of the Secretariat of a Ministry that administrates land, transport, etc. Now the Minister has an interest for open data, and instructs you to decide the open data policy of the Ministry. However, individual divisions are not positive for open data, because they have no troubles for daily work even if they don't open their data, though they use various spatial data such as land, water, road, housing, railway etc. Describe three ideas to do in about 15 lines, in total, in order to proceed the open data policy.