Version RC/5

EGT2
ENGINEERING TRIPOS PART IIA

Monday 28 April 2013 2 to 3.30

Module 3D8

BUILDING PHYSICS AND ENVIRONMENTAL GEOTECHNICS

Answer not more than ***three*** *questions.*

All questions carry the same number of marks.

The ***approximate*** *percentage of marks allocated to each part of a question is indicated in the right margin.*

Write your candidate number ***not*** *your name on the cover sheet.*

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Attachment: 3D8 Building Physics and Env. Geotechnics Data Book (17 pages).
Supplementary page: one extra copy of Fig. 2 (Question 2)
Engineering Data Book

You may not start to read the questions printed on the subsequent pages of this question paper until instructed to do so.

1 (a) Explain the terms pressure, pressure head and potential head with respect to a fluid saturating a porous media. [10%]

(b) A soil deposit has two horizontal layers of thicknesses L_1 and L_2 that have hydraulic conductivities of K_1 and K_2 respectively. Derive a relationship for the equivalent vertical hydraulic conductivity. [20%]

(c) A saturated soil deposit has two layers of silt and sand as shown in Fig. 1 overlying a weathered bedrock. The thickness of the silt layer is 6 m. The hydraulic conductivities of silt and sand are 2.05×10^{-4} m s^{-1} and 3×10^{-3} m s^{-1} respectively and the void ratio for both layers is 0.6. Any new rain water falling on the surface of the deposit takes 8.5 hours on average to reach the top of the bedrock. Assuming vertical flow through the silt and sand layers and a hydraulic gradient of 1, calculate the thickness of the sand layer. [30%]

(d) A toxic contaminant is spilt on the surface of the soil layer at point A shown in Fig.1. Assuming one-dimensional diffusion, calculate the shortest time for the contaminant to reach points B and C in the soil strata. Assume that there is no rainfall after the spillage and the seepage through the weathered bedrock is very slow. The flow in sand is parallel to the bedrock. Point B is directly below point A at the silt/sand interface while point C is 150 m to the right of B at the same elevation. The coefficient of diffusion of the toxic contaminant in the silt is $D_d^* = 5.8 \times 10^{-6}$ m^2 s^{-1}. Two standpipes inserted at a 10 m interval as shown in Fig. 1 show water levels of 1.2 m and 0.3 m above the ground surface. Comment on the contaminant transport mechanisms at play in this problem. [40%]

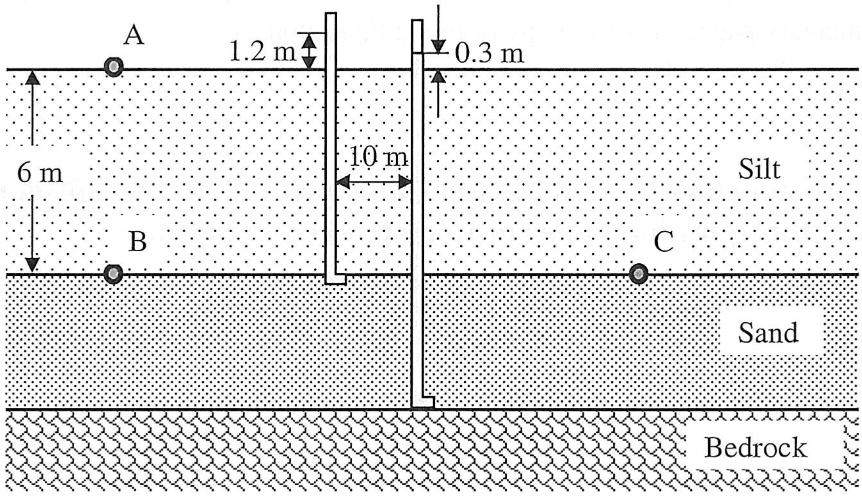

Fig. 1

2 (a) Explain the terms 'specific heat capacity', 'volumetric heat capacity' and 'thermal diffusivity' with respect to heat flow in a porous media. [15%]

(b) The Laplace equation for flow of ground water in porous media can be solved by constructing a flownet. Using the analogy of ground water flow, derive for a two-dimensional problem the relationship between the heat flow H per metre, the thermal conductivity λ, the number of heat flow lines N_f and isotherms N_T for a temperature difference of ΔT. [25%]

(c) An industrial plant has a very long underground storage tank that is used to store process fluids at a temperature of 70 °C. As shown in Fig. 2, the tank is buried at a depth of 4 m below ground surface in a Gault clay deposit that has a unit weight of 19.3 kN m^{-3}. The depth of the tank is 3 m and its width is 9 m. The thermal diffusivity of Gault clay is 1.162×10^{-6} m^2 s^{-1} and its specific heat capacity is 1400 J kg^{-1} K^{-1}. The air temperature at the ground surface can be assumed to be constant at 10 °C.

(i) Draw a 'heat flow net' at steady state of the problem on the extra copy of Fig. 2 provided. You must submit this copy with your script. [25%]

(ii) Determine the temperature at points A, B and C. [15%]

(iii) Estimate the heat flow through the ground surface. Comment on the accuracy of your answer. [20%]

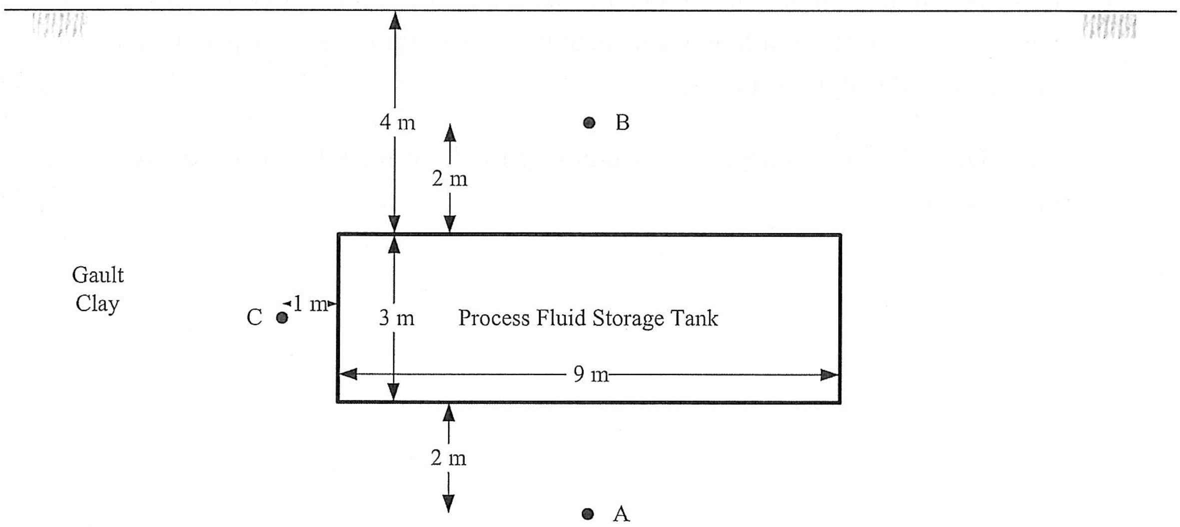

Fig. 2

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3 (a) The pressure difference Δp for flow through openings is expressed as:

$$\Delta p = \frac{1}{C_{orif}^2}\left(\frac{1}{2}\rho v^2\right)$$

where ρ is the density of air, v is the air velocity, and C_{orif} is the dimensionless discharge coefficient. Show that the buoyancy-driven volumetric flow Q through a warm room with upper and lower openings whose centres are separated by height H may be estimated by:

$$Q = A^* \cdot C_{orif}\sqrt{2gH\left(\frac{273}{T_o} - \frac{273}{T_i}\right)}$$

Where A^* is an effective area of opening and T_o and T_i are the external and internal temperatures, respectively. [40%]

(b) A small theatre has floor area of 100 m^2 and height of 10 m. The areas of the lower and upper openings on one facade are 0.8 m^2 and 0.4 m^2, respectively. The height difference between the openings is 7 m. The theatre is maintained at a temperature of 20 ^{o}C whilst the external air temperature is 5 ^{o}C. Take C_{orif} as 0.61.

(i) Determine the ventilation rate due to buoyancy for the theatre. [20%]

(ii) Calculate the resulting air changes per hour in the theatre, and the ventilation heat loss in kW. [20%]

(iii) Given that a minimum air change rate of 10 litres per second is required per person for adequate ventilation, calculate the maximum number of people that can be accommodated in the theatre. [10%]

(iv) Describe two strategies for increasing the buoyancy-driven ventilation rate of the theatre. [10%]

4 (a) A room is heated by a vertical panel radiator, fixed to an external wall. The radiator measures 0.8 m by 1.0 m. The total area of the other surfaces in the room is 50 m^2. Calculate the net radiation heat transfer from the radiator to the other surfaces in Watts. The mean surface temperature of the radiator is maintained at 75 ^oC and the emissivity of the radiator surface is 0.97. Assume that the view factor from the radiator to other room surfaces is 1. The temperature of all other surfaces in the room is 21 ^oC and their surface emissivity is 0.9. [35%]

(b) The room described above has a floor area of 20 m^2 and it is occupied by 2 people. A minimum air change rate of 5 litres per second is required per person for adequate ventilation. The external wall area of the room is 15 m^2 and the window area is 5 m^2. The U-values of the wall and window are 0.35 and 1.5 W m^{-2} K^{-1} respectively. The daily average solar radiation transmitted into the room is 90 W. Show a network diagram representing this problem, including all heat losses and gains to the internal air temperature node. Is the radiator described in part (a) adequate to maintain a daily average temperature of 21 ^oC during the winter period, when the external average temperature is 5 ^oC? Justify your answer. [30%]

(c) The radiator described in part (a) is mounted a few centimetres away from the external wall. As an energy saving measure, it is decided to fix a shiny metal foil to the wall area directly behind the radiator. The surface temperature of this area of the wall, behind the radiator, remains stable at 40 ^oC. Determine the radiant heat transfer from the radiator to the wall behind it with and without the metal foil. Take the emissivity of the metal foil as 0.04 and the emissivity of the wall surface behind the radiator as 0.9. [35%]

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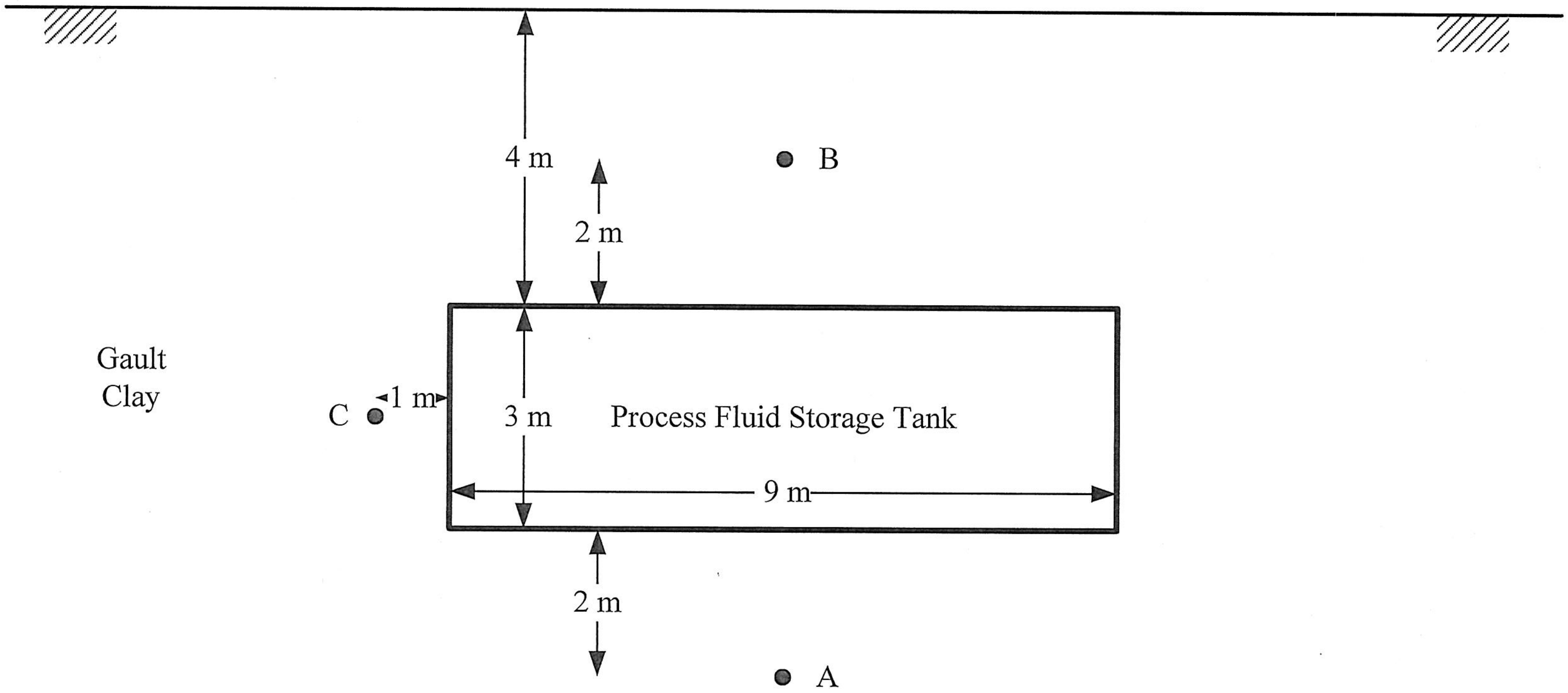

Extra copy of Fig. 2