ENGINEERING TRIPOS PART IIB

Monday 23 April 2012 2.30 to 4

Module 4A8

ENVIRONMENTAL FLUID MECHANICS

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.*

Attachments: Environmental Fluid Mechanics Data sheets (7 pages).

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculator allowed

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

ns03

1 (a) Describe clearly what are

(i) geostrophic and Ekman layer flows; [20%]

(ii) density driven flows with some examples. [15%]

(b) What are the sources and sinks for kinetic energy of turbulent motions in the atmosphere? By considering the physical mechanism for turbulence generation in the atmosphere on a sunny day with steady wind, deduce conditions based on the Richardson number for the atmospheric flow stability. [35%]

(c) Name the factors which can influence atmospheric flows at

(i) synoptic scale; [10%]

(ii) meso scale; [10%]

(iii) micro scale. [10%]

2 A heavy gas with density of 1.8 kg m^{-3} from a chemical plant flows down a slope of angle θ and into a village as shown in Fig. 1, creating a danger to the villagers. The village is located at 1000 m from the source of the gas. Assume that the variations in the lateral direction are small and that the entrainment coefficient is $\alpha = 0.05$. The air density is 1.2 kg m^{-3}.

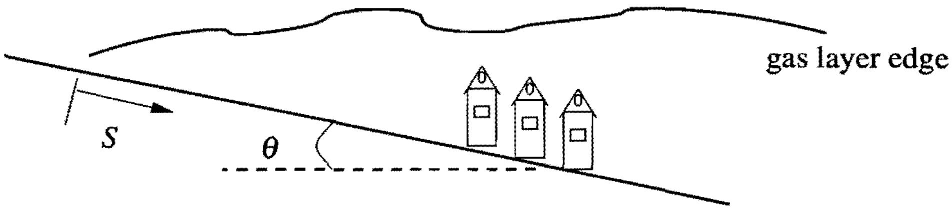

Fig. 1

(a) Setup the conservation equations and solve them using self-similarity to show that the gas layer height varies as αS, where S is the distance marked in Fig. 1, and the flow velocity remains constant. [45%]

(b) Using the solution in (a), estimate the thickness of the gas layer when it encounters the village. [10%]

(c) At a distance of 10 m from the source, the gas layer thickness is 1 m, the gas density is 1.8 kg m^{-3} and the average velocity is 10 m s^{-1}. Estimate the mass fraction of the gas in the layer when it encounters the village. [45%]

3 (a) Discuss briefly the concept of *mixing height* and how it is related to the emergence of a fumigation. [50%]

(b) Consider a plume from a line source of strength Q per unit length, in a uniform wind U. The source is located at a height h from the ground, which is taken as a fully-reflecting boundary. An inversion layer exists at a height $2h$ above the ground. Assume homogeneous turbulence characteristics in the region between the ground and the inversion layer, and treat this layer as a fully-reflecting boundary. Derive an equation for the concentration of matter emitted by the source. [50%]

4 (a) Construct a simple model for the radiative balance in the atmosphere and hence derive an expression for the average surface temperature of the earth. Clearly state the assumptions made. Through reference to your model, discuss why increased CO_2 emissions cause an increase in the surface temperature. [50%]

(b) Discuss briefly the key constituents of *smog*, including the key reactions involved in NO, NO_2 and O_3 interactions. What is the *photostationary state*? [50%]

END OF PAPER