Name: _____

NE 602 Radiation Protection Engineering

Open Books and Notes Final Examination, May 12, 1997

1. Indicate whether the following statements are true (T) or false (F). *[30 points]*

( ) The main diffusion mechanism for atmospheric dispersion is the random motion of the individual molecules in the air.

( ) A balloon tied to a brick is dropped over a 100-m cliff. When the balloon reaches the base of the cliff, the air temperature of the gas in the balloon will have increased by at least 0.5 C.

( ) Decreasing the averaging time over which measurements are made of the air concentration of some pollutant released upwind at a steady rate increases the observed averaged concentration.

( ) The ground-level concentration of an air-borne radionuclide always decreases with increasing downwind distance from an elevated release point (which releases radionuclides at a steady rate).

( ) For a slightly stable atmosphere the rate of horizontal dispersion of radionuclides is always greater than that of vertical dispersion at the same downwind distance from the discharge point.

( ) A wind rose is a sandstone formation created by wind erosion.

( ) Thermal stratification in a small pond generally decreases pollutant concentrations in the surface water compared to that in the same pond without thermal stratification.

( ) For a polluted discharge into a river, the pollutant concentration after near-field mixing is greater than after fully lateral mixing.

( ) The concentration of a contaminant in river water far downstream from the discharge point depends both on the amount of contaminant in the discharge and on the concentration in the discharge.

( ) The diffusion mechanism in underground aquifers is the turbulence eddies in the flowing water.

( ) The *intake-to-food-product transfer factors* can be used in analyses of short-term contaminations from accidental radionuclide releases.

( ) The elemental concentration ratio in some organism is smaller for stable isotopes than that for radioactive isotopes of the same element.

( ) The concentration of ^{90}Sr in the muscle of a cow is greater than that of ^{137}Cs for a cow which grazes on pasture grass that is contaminated by equal activities of the two radioisotopes.

( ) Reference Man obtains more of his body water from his food than from his drink.

( ) For a steady release rate into an exposure pathway, an estimate of the radionuclide concentration in a human food source based on a steady-state analysis may by greater than an estimate made with a transient model.

2. Two cooling towers are located a distance δy apart. The discharge plume from each has an effective discharge height of h_e, and each is discharging the same gaseous radionuclide (with decay constant λ) at a steady rate of Q Bq/s.

   (a) Derive an expression for the ground level activity concentration in the air at a distance x directly downwind from the midpoint between the towers when the wind is blowing at a constant speed u perpendicularly to the line between the two towers. Use standard notation or define any non-standard symbols used. *[10 points]*

   (b) To evaluate your expression for clear night time conditions when the wind speed is 2 m/s, what values of the diffusion parameters σ_y and σ_z would you use for a downwind distance of 1 km? Use the Pasquill-Gifford diffusion parameters. *[5 points]*

3. The ground level concentration of molecular radioiodine (I_2) over a pasture under neutral atmospheric conditions is measured to be 1.5 MBq m^{-3}. Estimate the rate at which radioiodine is deposited on the pasture grass in Bq kg^{-1} s^{-1}. *[10 points]*

4. 15 TBq of a very long lived radionuclide is accidentally discharged into river which has an average width of 50 m, and average depth of 1.5 m, and a flow rate of 70000 m^3 per hour. The longitudinal dispersion coefficient D_x for this river is known to be about 20 m^2 s^{-1}. What will be the maximum concentration of this radionuclide at a location 20 km downstream from the accident site? *[15 points]*

5. A simple model describing the concentration $X(t)$ (Bq/g) of a radionuclide with decay constant λ in the breast meat of a chicken is given by differential equation

$$\frac{dX(t)}{dt} = \frac{f}{M}Q(t) - (\lambda + \lambda_r)X(t).$$

   Here λ_r is the rate constant (s^{-1}) for elimination of the radionuclide the breast which has mass M (g), f is the fraction of the ingested radionuclide element that goes to the breast, and $Q(t)$ (Bq/s) is the average rate of activity ingestion by the chicken.

   (a) Derive an expression for the activity in the breast meat as a function of time after a chicken first begins to eat contaminated feed at a constant rate Q_o. *[5 points]*

   (b) What is the input-to-breast-meat transfer factor F for this model? *[5 points]*

   (c) From studies using stable isotopes of the radionuclide element, it is found that the elimination rate $\lambda_r = 10^{-4}$ s^{-1} and the transfer factor (for the stable isotopes) $F_s = 10^{-3}$. What is the transfer factor F for the radioactive form of the same element is the radioactive half-life is 10^3 seconds? *[5 points]*

6. The average US adult human consumes about 26 g d^{-1} of chicken. (a) If this average human were to consume chicken that ingest 2 pCi d^{-1} of ^{137}Cs from contaminated feed, estimate the annual ^{137}Cs activity consumed by the human. (b) What would be the annual committed dose equivalent (Sv) received by the red marrow of such an individual? *[15 points]*