Name ____

Name ____

Elementary Fluid Mechanics CEE 577
Spring 2020
Exam 1

Circle the correct answer or fill in the blank

1. (**3pt**) Steady-state is a dynamic equilibrium condition where the accumulation term (that is, dc/dt =) is equal to
(a) positive
(b) zero
(c) negative

2. (**3pt**) A collected set of terms in a mass-balance model known as the characteristic value that represents "sinks that deplete matter" is called
(a) the residence time
(b) the forcing function
(c) the eigenvalue

3. (**3pt**) The time it takes for a water body to complete a fixed percentage of its recovery is called _response time___.

Solve and show your work.

Mass Balance, Completely Mixed Systems
4. (**6 pts**) A lake has the following characteristics:

Volume =50,000 m^3
Mean depth = 2m
Inflow = 7,000 m^3
Outflow = 8,000 m^3
Temperature = 27.5° C

The lake receives the input of a pollutant from two sources: a factory discharge of 50 kg d^{-1}. The inflow stream that has a concentration of 10 mg L^{-1}. If the pollutant decays at a rate of 0.25 d^{-1} at 20°C (θ=1.05),

(a) Determine the inflow concentration
(b) transfer function
(c) water residence time
(d) pollutant residence time

(a) inflow concentration

$$c_{in} = \frac{W_{total}}{Q_{in}}$$

$$W = W_{inflow} + W_{factory}$$

Name ____

$$W_{factory} = 50\frac{kg}{d} = 50{,}000\frac{g}{d}, \qquad W_{inflow} = Q_{inflow} * c_{stream} = 7{,}000\frac{m^3}{d} * \left(10\frac{g}{m^3}\right) = 70{,}000\frac{g}{d}$$

$$W = W_{inflow} + W_{factory} = 50{,}000\frac{g}{d} + 70{,}000\frac{g}{d} = 120{,}000\frac{g}{d}$$

$$c_{in} = \frac{W_{total}}{Q_{in}} = \frac{120{,}000\frac{g}{d}}{7{,}000\frac{m^3}{d}} = 17.14\frac{g}{m^3} = 17.14\frac{mg}{L} = 0.0171\frac{kg}{m^3}$$

(b) transfer function

$$\beta = \frac{c_{lake}}{c_{in}} = \frac{Q_{in}}{Q_{out} + k_{27.5}V}$$

$$k_{27.5} = k(20) * \theta^{T-20}$$

$$k_{27.5} = (0.25\ d^{-1}) * (1.05)^{27.5-20} = .360\ d^{-1}$$

$$\beta = \frac{c_{lake}}{c_{in}} = \frac{Q_{in}}{Q_{out} + k_{27.5}V} = \frac{7{,}000\frac{m^3}{d}}{8{,}000\frac{m^3}{d} + 0.36\ d^{-1}(50{,}000\ m^3)} = 0.269$$

(c) water residence time

$$\tau_w = \frac{V}{Q_{out}} = \frac{50{,}000\ m^3}{8{,}000\frac{m^3}{d}} = 6.25\ d$$

(d) pollutant residence time

$$\tau_c = \frac{V}{Q_{out} + k_{27.5}V} = \frac{50{,}000\ m^3}{8{,}000\frac{m^3}{d} + 0.36\ d^{-1}(50{,}000\ m^3)} = 1.92$$

Name ____

Circle the correct answer or fill in the blank

5. (**3pt**) __________________specifies that mass flux is proportional to the gradient (rate of change) of concentration.

(a) Stokes' law
(b) Fick's first law
(c) Fick's second law

6. (**3pt**) ________________ is the distance over which diffusion takes place.

(a) Mixing length
(b) Half-life
(c) Phase shift

7. (**3pt**) For mixing and transport, we use the term ____dispersion______________ when dealing with narrow, flowing bodies of water such as one-dimensional streams and estuaries. For lakes, bays, and vertical transport we usually employ __diffusion_____.

Solve and show your work.

8. (**6 pts**) A point source is discharged into an estuary having the following characteristics:

Dispersion coefficient	10^6	m^2d^{-1}
Flow	4×10^4	m^3d^{-1}
Width	100	m
Depth	5	m

The pollutant decays at a rate of 0.3 d^{-1} at T= 20°C with Q_{10} =1.7. The estuary has an ambient temperature of 30.5° C.

(a) Determine the reaction rate for the ambient temperature

$$k_{30.5} = k(20) * \theta^{T-20}$$

$$\theta = Q_{10}^{0.1} = (1.7)^{0.1} = 1.0545$$

$$k_{27.5} = (0.3\ d^{-1}) * (1.0545)^{30.5-20} = .5237\ d^{-1}$$

(b) What mass loading could be input to this system under steady-state conditions if the allowable concentration at the outfall is 25 ppb? Express your results in kg d^{-1}. Assume complete lateral and vertical mixing at the outfall.

Name ____

Solve for velocity

$$U = \frac{Q}{A_c} = \frac{4 \times 10^4 \; m^3 d^{-1}}{(5\; m \times 100\; m)} = 80\; m\; d^{-1}$$

Solve for Eq 9.55 (MFR Model to Estuaries) to perform an assimilative capacity calculation

For 25 ppm (25 mg/m^3)

$$W = Q * c_0 \sqrt{1 + \frac{4(k)E}{U^2}}$$

$$W = \left(4 \times 10^4 \; \frac{m^3}{d}\right) * \left(25 \frac{mg}{m^3}\right) \sqrt{1 + \frac{4(.5237)10^6}{(80)^2}} = 18{,}119{,}604.6 \frac{mg}{d}$$

$$W = 18.12 \frac{kg}{d}$$

Name ____

Circle the correct answer or fill in the blank

9. (**3pt**) ____________________ is derived from a momentum balance for an open channel and provides a means to relate velocity to channel characteristics.

(a) The 7Q10
(b) The Fisher formula
(c) Manning's Equation

10. (**3pt**) ________________ refers to a topographic map showing the depth contour lines of a lake/impoundment

(a) Limnology
(b) Hydrography
(c) Bathymetry

11. (**3pt**) Solids in natural waters with a primary origin from the drainage basin are referred to as __allochthonous____ solids.

Solve and show your work.

12. (**6 pts**) Determine the settling velocities for silt (ρ_s = 2.65 g cm^{-3}) for the cases of diameters (a) of 15 and (b) 25 µm. Assume that all particles are perfect spheres (α =1.0 and *d* = diameter).

$$v_s = 0.033634\,\alpha\,(\rho_s - \rho_w)d^2$$

(a) For 15 um

$$v_s = 0.033634(1)\,(2.65 - 1)(15)^2$$

$$v_s = 12.49\;m\;d^{-1}$$

(a) For 25 um

$$v_s = 0.033634\,(1)\,(2.65 - 1)(25)^2$$

$$v_s = 34.69\;m\;d^{-1}$$