M.E. (Civil) 2nd Semester Final Examination, 2014

AIR POLLUTION CONTROL ENGINEERING

(CE 1019)

Time : 3 hours | Full Marks : 70

Answer any five questions

1. (a) A conventional type cyclone having standard proportions is having diameter D = 1.0 m. Flow rate of dirty gas Q = 150 m^3/min. Particle density may be taken as 1600 kg/m^3 and density of air 1.204 kg/m^3. If the particle size distribution is as follows, find the collection efficiency of the cyclone. With a sketch, also show the relevant dimensions of the cyclone.

Particle size (d_p) (μm)	% mass in that size range
0 – 2	1
2 – 4	9
4 – 6	10
6 – 10	30
10 – 18	30
18 – 30	14
30 – 50	5
50 – 100	1

(b) What is stokes diameter for a suspended particle? How it differs from the aerodynamic particle diameter? How are they related mathematically?

(c) What is $PM_{2.5}$?

(8+5+1)

2. (a) With suitable sketch, explain the principle and operation of an electrostatic precipitator. Indicate the merits and limitations of ESPs.

(b) Design as ESP (dimensions of plates and number of plates) for the situation indicated below. The ESP should achieve an efficiency of 99%.

Airflow Q = 2000 m^3/min

Particle diameter d_p = 0.5 μm

Average particle charge q = 10 electron charges

Electric field E = 50000 V/m

Viscosity of air = 1.81 x 10^{-5} kg/m.s

Mean free path of the gas = 0.066 μm

(6+8)

3. (a) A baghouse with 5 compartments, each having 1000 m^2 of cloth area, is used to filter a dusty gas with a loading of 0.01 kg/m^3 and a flow rate of 100 m^3/s. K_1 and K_2 have been determined to be 40000 $N.s/m^3$ and 60000 /s and each cleaning takes 3 min. If the maximum allowable pressure drop ΔP_{max} = 2500 Pa, calculate the run time per cycle.

(b) With sketch, explain the operation of any device for control of gaseous pollutants.

(c) Name one adsorbent that is used in air pollution control. Mention the pollutant gas which may be removed by the adsorbent.

(8+4+2)

4. (a) What are the principal factors that cause plume rise for a stack?

(b) A 750 MW coal-fired power plant has a 250 m stack with inside radius 4 m. The exit velocity of the stack gases is estimated at 1.5 m/s, at a temperature of 140°C. Ambient temperature is 25°c and winds at stack height are estimated to be 5 m/s. Estimate the effective stack height of the stack if the atmosphere is slightly unstable, class C.

(c) A power plant burns 5.45 tonnes of coal per hour and discharges the combustion products through a stack that has an effective height of 75 m. The coal has a sulphur content of 4.2 percent and the wind velocity at the top of the stack is 6.0 m/s. The atmospheric conditions are moderately to slightly unstable. Determine the ground level concentration of SO_2 at a location which is 3.0 km downwind and 0.4 km crosswind on any side of the centerline.

(2+6+6)

5. (a) Mention two categories of stationary sources of air pollution with examples. What are primary and secondary air pollutants?

(b) According to the Bharat Stage IV norms for automobile exhaust, which pollutants are monitored in the petrol and diesel-driven automobiles? How the catalytic convertors are helpful in reducing the automotive pollution?

(c) The range of particle sizes formed in a process is largely dependent on the types of particle formation mechanisms present. The general size range of particles can be estimated by simply recognizing which particle formation mechanisms are most important in the process being evaluated. Match the particle formation mechanism with its correct size range.

Particle formation mechanism		Size range (μm)
i.	Physical attrition	a. 0.1 - 20
ii.	Combustion particle burnout	b. 10 – 1000
iii.	Homogeneous and heterogeneous nucleation	c. 1 – 100
iv.	Droplet evaporation	d. 0.1 – 1

(d) Briefly describe the mechanism of formation of photochemical smog. What are its components and what adverse effects are caused by photochemical smog?

(4+4+2+4)

6. (a) What is albedo? On an average, how much of Earth's albedo is contributed by clouds and atmosphere? The solar flux arriving at the outer edge of the atmosphere, varies by ±3.3% as the earth moves in its orbit. By how many degrees would the equivalent temperature for the Earth vary as a result? Explain how presence of certain gases helps warming of the Earth's lower atmosphere.

(b) Explain how CFC released by human activities may cause destruction of stratospheric ozone layer.

(c) What is acid rain? How is it caused? What are the adverse effects of acid rain?

(7+3+4)

7. (a) The National Ambient Air Quality Standard specifies the annual average concentration of 50 $\mu g/m^3$ for SO_2. How is the annual average concentration estimated? Express this value is ppm.

(b) A bar with a volume 500 m^3 has 50 smokers in it, each smoking two cigarettes per hour. An individual cigarette emits, among other things, about 1.40 mg of formaldehyde (HCHO). Formaldehyde converts to carbon dioxide with a reaction rate coefficient K = 0.4/hour. Fresh air enters the bar at the rate of 1000 m^3/hour and stale air leaves at the same rate. Estimate the steady state concentration of formaldehyde in the air, assuming complete mixing. At 20°C and 1 atm of pressure, how does the result compare with threshold for eye irritation of about 0.05 ppm?

(c) Suppose the air in the bar is clean when it opens at 5 P.M. If formaldehyde with reaction rate K = 0.4/hour is emitted from cigarette smoke at the constant rate (as indicated previously) starting at 5 P.M., what would be the concentration at 6 P.M.?

(4+5+5)

8. (a) How NO_x reduction can be achieved in coal-fired thermal power plants during the combustion process (mention one process)? Discuss about one process of pre-combustion control that is applied to reduce SO_2 emissions from fossil-fuel combustion.

(b) What is adiabatic lapse rate? If the temperature of the atmosphere is decreasing at a rate of 5.5°C per kilometer, how the stability of the atmosphere is characterized? When the plume emitting from a stack takes the 'fanning' shape?

(c) What is inversion? How is it caused?

(5+5+4)

Pasquill Stability Category	c	d
A	24.1670	2.5334
B	18.3330	1.8096
C	12.5000	1.0857
D	8.3330	0.72382
E	6.2500	0.54287
F	4.1667	0.36191

$$\sigma_z = ax^b$$

Pasquill Stability Category	x (km)	a	b
B	≤.20	90.673	0.93198
	0.21 - 0.40	98.483	0.98332
	>0.40	109.300	1.09710
C	All	61.141	0.91465
D	≤.30	34.459	0.86974
	0.31 - 1.00	32.093	0.81066
	1.01 - 3.00	32.093	0.64403
	3.01 - 10.00	33.504	0.60486
	10.01 - 30.00	36.650	0.56589
	>30.00	44.053	0.51179